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FIELD AND GENERAL ORNITHOLOGY

HANDBOOK

OF

FIELD AND GENERAL

ORNITHOLOGY

A MANUAL OF THE STRUCTURE AND CLASSIFICATION OF BIRDS

WITH INSTRUCTIONS FOR

COLLECTING AND PRESERVING SPECIMENS

BY

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NOTE.—The Publishers beg to give notice that copies of this English Edition of Dr. Coues's Book cannot be introduced into the United States of America.

PUBLISHERS' PREFACE

The present volume consists of two distinct parts.

Part I., entitled "Field Ornithology," contains the necessary instructions for the observation and collection of birds in the field, and for the preparation and preservation of specimens for scientific study in the cabinet.

Part II., entitled "General Ornithology," is a technical treatise on the classification, the zoological characters, and the anatomical structure of the class of Birds, in which the examples cited in illustration of the principles of Ornithology have for the most part been redrawn by the author from British instead of American birds.

With the further exception of a few verbal changes, and slight abridgment in one or two places, made by the author in revising the proofs, the present "Handbook" is a reprint of the portions of the "Key" above specified.

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PART I

FIELD ORNITHOLOGY

BEING

A MANUAL OF INSTRUCTION FOR COLLECTING, PREPARING, AND PRESERVING BIRDS

FIELD ORNITHOLOGY

FIELD ornithology must lead the way to systematic and descriptive ornithology. The study of birds in the field is an indispensable prerequisite to their scientific study in the library and the museum. Directions for observing and collecting birds, for preparing and preserving them as objects of natural history, will greatly help the student to become a successful ornithologist, if he will faithfully and intelligently observe these rules. It is believed that the practical instructions which the author has to give will, if followed out, enable any one who has the least taste or aptitude for such pursuits to become proficient in the necessary qualifications of the good working ornithologist. These instructions are derived from the writer's own experience, reaching in time over thirty years, and extending in area over large portions of North America. Having made in the field the personal acquaintance of most species of North American birds, and having shot and skinned with his own hands several thousand specimens, he may reasonably venture to speak with confidence, if not also with authority, respecting methods of study and manipulation. Feeling so much at home in the field—with his gun for destroying birds, and his instruments for preserving their skins—he wishes to put the most inexperienced student equally at ease; and therefore begs to lay formality aside, that he may address the reader as if chatting with a friend on a subject of mutual interest.

§ 1.—IMPLEMENTS FOR COLLECTING, AND THEIR USE

The Double-barrelled Shot Gun is your main reliance. Under some circumstances you may trap or snare birds, catch them with bird-lime, or use other devices; but such cases are exceptions to

the rule that you will shoot birds, and for this purpose no weapon compares with the one just mentioned. The soul of good advice respecting the selection of a gun is, *Get the best one you can afford to buy;* go the full length of your purse in the matters of material and workmanship. To say nothing of the prime requisite, safety, or of the next most desirable quality, efficiency, the durability of a high-priced gun makes it cheapest in the end. Style of finish is obviously of little consequence, except as an index of other qualities; for inferior guns rarely, if ever, display the exquisite appointments that mark a first-rate arm. There is really so little choice among good guns that nothing need be said on this score; you cannot miss it if you pay enough to any reputable maker or reliable dealer. But collecting is a specialty, and some guns are better adapted than others to your particular purpose. This is the destruction, as a rule, of small birds, at moderate range, with the least possible injury to their plumage. Probably three-fourths or more of the birds of any miscellaneous collection average under the size of a pigeon, and were shot within thirty yards. A heavy gun is therefore unnecessary, in fact ineligible, the extra weight being useless. You will find a gun of seven and a half to eight pounds weight most suitable. For similar reasons the bore should be small; I prefer fourteen gauge, and should not think of going over twelve. Length of barrel is of less consequence than many suppose; for myself, I incline to a rather long barrel—one nearer thirty-three than twenty-eight inches—believing that such a barrel may throw shot better; but I am not sure that this is even the rule, while it is well known that several circumstances of loading, besides some almost inappreciable differences in the way barrels are bored, will cause guns apparently exactly alike to throw shot differently. Length and crook of stock should of course be adapted to your figure—a gun may be made to fit you, as well as a coat. For wild-fowl shooting, and on some other special occasions, a heavier and altogether more powerful gun will be preferable.

Breech-loader *v.* **Muzzle-loader**, a case formerly argued, has long been settled in favour of the former. Provided the mechanism and workmanship of the breech be what they should, there are no valid objections to offset obvious advantages, some of which are these: ease and rapidity of loading, and consequent delivery of shots in quick succession; facility of cleaning; compactness and portability of ammunition; readiness with which different-sized shot may be used. This last is highly important to the collector, who never knows the moment he may wish to fire at a very different bird from such as he has already loaded for. The muzzle-loader must always contain the fine shot with which nine-tenths of your specimens will be secured; if in both barrels, you cannot

deal with a hawk or other large bird with reasonable prospects of success; if in only one barrel, the other being more heavily charged, you are crippled to the extent of exactly one-half of your resources for ordinary shooting. Whereas, with the breech-loader you will habitually use mustard-seed in both barrels, and yet can slip in a different shell in time to seize most opportunities requiring large shot. This consideration alone should decide the case. Moreover, the time spent in the field in loading an ordinary gun is no small item; while cartridges may be charged in your leisure at home. This should become the natural occupation of your spare moments. No time is really *gained;* you simply change to advantage the time consumed. Metal shells, charged with loose ammunition, and susceptible of being reloaded many times, may be used instead of any special fixed ammunition which, once exhausted in a distant place (and circumstances may upset the best calculations on that score), leaves the gun useless. On charging the shells, mark the number of the shot used on the outside wad; or better, use coloured wads—say plain white for dust shot, and red, blue, and green for certain other sizes. If going far away, take as many shells as you think can possibly be wanted—and a few more.

Experience, however, will soon teach you to prefer paper cartridges for breech-loaders. They may of course be loaded according to circumstances, with the same facility as metal shells, and even reloaded if desired. It is a good deal of trouble to take care of metal shells, to prevent loss, keep them clean, and avoid bending or indenting; while there is often a practical difficulty in recapping—at least with the common styles that take a special primer. Those fitted with a screw top holding a nipple for ordinary caps are expensive. Paper cartridges come already capped, so that this bother is avoided, and it is not ordinarily worth while to reload them. They are made of different colours, distinguishing various sizes of shot used without employing the coloured wads otherwise required. They may be taken into the field empty and loaded on occasion to suit; but it is better to pay a trifle extra to have them loaded at the shop. In such case, about four-fifths of the stock should contain mustard-seed, nearly all the rest about No. 7, a very few being reserved for about No. 4. Cost of ammunition is hardly appreciably increased; its weight is put in the most conveniently portable shape; the whole apparatus for carrying it loose and for loading the shells is dispensed with; much time is saved, the entire drudgery (excepting gun-cleaning) of collecting being avoided. I was prepared in this way during the summer of 1873 for the heaviest work I ever succeeded in accomplishing during the same length of time. In June, when birds were plentiful, I easily averaged fifteen skins a day, and occasionally made twice

as many. As items serving to base calculations, I may mention that in four months I used about two thousand cartridges, loaded, at $42 per M., with seven-eighths of an ounce of shot and two and three-fourths drachms of powder. Only about three hundred were charged with shot larger than mustard-seed. In estimating the size of a collection that may result from use of a given number of cartridges, it may not be safe for even a good shot to count on much more than half as many specimens as cartridges. The number is practically reduced by the following steps: Cartridges lost or damaged, or originally defective; shots missed; birds killed or wounded, not recovered; specimens secured unfit for preservation, or not preserved for any reason; specimens accidentally spoilt in stuffing, or subsequently damaged, so as to be not worth keeping; and finally, use of cartridges to kill game for the table.

Other Weapons, etc.—An ordinary *single-barrel* gun will of course answer; but is a sorry makeshift, for it is sometimes so poorly constructed as to be unsafe, and can at best be only just half as effective. This remark does not apply to any of the fine single-barrelled breech-loaders now made. You will find these very effective weapons, and they are not at all expensive. An arm now much used by collectors is a kind of breech-loading pistol, with or without a skeleton gun-stock to screw into the handle, and taking a particular style of metal cartridge, charged with a few grains of powder, or with nothing but the fulminate. They are very light, very cheap, safe and easy to work, and astonishingly effective up to twenty or thirty yards; making probably the best "second choice" after the matchless double-barrelled breech-loader itself. The *cane-gun* should be mentioned in this connection. It is a single-barrel, lacquered to look like a stick, with a brass stopper at the muzzle to imitate a ferule, countersunk hammer and trigger, and either a simple curved handle, or a light gunstock-shaped piece that screws in. The affair is easily mistaken for a cane. Some have acquired considerable dexterity in its use; my own experience with it is very limited and unsatisfactory; the handle always hit me in the face, and I generally missed my bird. It has only two recommendations. If you approve of shooting on Sunday, and yet scruple to shock popular prejudice, you can slip out of town unsuspected. If you are shooting where the law forbids destruction of small birds,—a wise and good law that you may sometimes be inclined to defy,—artfully careless handling of the deceitful implement may prevent arrest and fine. A *blow-gun* is sometimes used. It is a long slender tube of wood, metal, or glass, through which clay balls, tiny arrows, etc., are projected by force of the breath. It must be quite an art to use such a weapon successfully, and its employment is necessarily exceptional. Some uncivilised tribes are said to possess marvellous

skill in the use of long bamboo blow-guns; and such people are often valuable employés of the collector. I have had no experience with the noiseless *air-gun*, which is, in effect, a modified blow-gun, compressed air being the explosive power. Nor can I say much of various methods of *trapping* birds that may be practised. On these points I must leave you to your own devices, with the remark that horse-hair *snares*, set over a nest, are often of great service in securing the parent of eggs that might otherwise remain *unidentified*. I have no practical knowledge of *bird-lime*. A method of *netting* birds alive, which I have tried, is both easy and successful. A net of fine green silk, some eight or ten feet square, is stretched perpendicularly across a narrow part of one of the little brooks, overgrown with briers and shrubbery, that intersect many of our meadows. Retreating to a distance, the collector beats along the shrubbery making all the noise he can, urging on the little birds till they reach the almost invisible net and become entangled in trying to fly through. I have in this manner taken a dozen sparrows and the like at one "drive." But the gun can rarely be laid aside for this or any other device.

Ammunition.—The best *powder* is that combining strength and cleanliness in the highest compatible degree. In some brands too much of the latter is sacrificed to the former. Other things being equal, a rather coarse powder is preferable, since its slower action tends to throw shot closer. Some numbers are said to be "too quick" for fine breech-loaders. Inexperienced sportsmen and collectors almost invariably use too coarse *shot*. Then two evils result: The number of pellets in a load is decreased, the chances of killing being correspondingly lessened; and the plumage is badly injured, either by direct mutilation, or by subsequent bleeding through large holes. As already hinted, shot cannot be too fine for your routine collecting. Use "mustard-seed," or "dust-shot," as it is variously called; it is smaller than any of the sizes usually numbered. As the very finest can only be procured in cities, provide yourself liberally on leaving any centre of civilisation for even a country village, to say nothing of remote regions. A small bird that would have been torn to pieces by a few large pellets, may be riddled with mustard-seed and yet be preservable; moreover, there is, as a rule, little or no bleeding from such minute holes, which close up by the elasticity of the tissues involved. It is astonishing what large birds may be brought down with these tiny pellets. I have killed hawks with such shot, knocked over a wood-ibis at forty yards, and once shot a wolf dead with No. 10—though I am bound to say the animal was within a few feet of me. After dust-shot, and the nearest number or two, No. 8 or 7 will be found most useful. Water-fowl, thick-skinned sea-birds like loons, cormorants, and pelicans, and a

few of the largest land-birds, require heavier shot. I have had no experience with the substitution of fine gravel or sand, much less water, as a projectile; besides shot I never fired anything at a bird except my ramrod, on one or two occasions, when I never afterward saw either the bird or the stick. Cut felt *wads* are the only suitable article. Ely's "chemically prepared" wadding is the best. It is well, when using plain wads, *occasionally to drive a greased one through the barrel.* Since you *may sometimes run out of wads* through an unexpected contingency, always keep a wad-cutter to fit your gun. You can make serviceable wads of pasteboard, but they are inferior to felt. Cut them on the flat sawn end of a stick of firewood. Use a wooden mallet, instead of a hammer or hatchet, and so save your cutter. Soft paper is next best after wads; I have never used rags, cotton, or tow, fearing these tinder-like substances might leave a spark in the barrels. Crumbled leaves or grass will answer at a pinch.

Other Equipments.—(*a*) *For the gun.* A gun-case will come cheap in the end, especially if you travel much. The usual box, divided into compartments, and well lined, is the best, though the full-length leather or india-rubber cloth case answers very well. The box should contain a small kit of tools, such as mainspring-vice, nipple-wrench, screw-driver, etc. A stout hard-wood cleaning-rod, with wormer, will be required. It is always safe to have parts of the gun-lock, especially mainspring, in duplicate. For muzzle-loaders extra nipples and extra ramrod heads and tips often come into use. For breech-loaders the apparatus for charging the shells is practically indispensable. (*b*) *For ammunition.* Metal shells or paper cartridges may be carried loose in the large lower coat pocket, or in a leather satchel. There is said to be a chance of explosion by some unlucky blow, when they are so carried, but I never knew of an instance. Another way is to fix them separately in a row in snug loops of soft leather sewn continuously along a stout waist-belt; or in several such horizontal rows on a square piece of thick leather, to be slung by a strap over the shoulder. But better than anything else is a stout linen *vest*, similarly furnished with loops holding each a cartridge; this distributes the weight so perfectly, that the usual "forty rounds" may be carried without feeling it. The appliances for loose ammunition are almost endlessly varied, so every one may consult his taste or convenience. But now that everybody uses the breech-loader, shot-pouches and powder-flasks are among the things that were. (*c*) *For specimens.* You must always carry *paper* in which to wrap up your specimens, as more particularly directed beyond. Nothing is better for this purpose than writing-paper; "rejected" or otherwise useless MSS. may thus be utilised. The ordinary game-bag, with leather back and network front, answers

very well; but a light basket, fitting the body, such as the creel used by anglers, is the best thing to carry specimens in. Avoid putting specimens into *pockets*, unless you have your coat-tail largely excavated; crowding them into a close pocket, where they press each other, and receive warmth from the person, will injure them. It is always well to *take a little raw cotton into the field, to plug up shot-holes, mouth, nostrils, or vent, immediately if required.* (*d*) *For yourself.* The indications to be fulfilled in your clothing are these: Adaptability to the weather; and since a shooting-coat is not conveniently changed, while an overcoat is ordinarily ineligible, the requirement is best met by different underclothes. Easy fit, allowing perfect freedom of muscular action, especially of the arms. Strength of fabric, to resist briers and stand wear; velveteen and corduroy are excellent materials. Subdued colour, to render you as inconspicuous as possible, and to show dirt the least. Multiplicity of pockets—a perfect shooting-coat is an ingenious system of hanging pouches about the person. Broad-soled, low-heeled boots or shoes, giving a firm tread even when wet. Close-fitting cap with prominent visor, or low soft felt hat, rather broad-brimmed. Let india-rubber goods alone; the field is no place for a sweat-bath.

Qualifications for Success.—With the outfit just indicated you command all the required appliances that you can *buy*, and the rest lies with yourself. Success hangs upon your own exertions; upon your energy, industry, and perseverance; your knowledge and skill; your zeal and enthusiasm, in collecting birds, much as in other affairs of life. But that your efforts—maiden attempts they must once have been if they be not such now—may be directed to best advantage, further instructions may not be unacceptable.

To Carry a Gun without peril to human life or limb is the *a b c* of its use. "There's death in the pot." Such constant care is required to avoid accidents that no man can give it by continual voluntary or conscious effort: safe carriage of the gun must become an unconscious habit, fixed as the movements of an automaton. The golden rule and whole secret is: *the muzzle must never sweep the horizon;* accidental discharge should send the shot into the ground before your feet, or away up in the air. There are several safe and easy ways of holding a piece; they will be employed by turns to relieve particular muscles when fatigued. 1. Hold it in the hollow of the arm (preferably the left, as you can recover to aim in less time than from the right), across the front of your person, the hand on the grip, the muzzle elevated about 45°. 2. Hang it by the trigger-guard hitched over the forearm brought round to the breast, the stock passing behind the upper arm, the muzzle pointing to the ground a pace or so in front of you. 3. Shoulder it, the hand on the grip or heel-plate, the muzzle pointing upward at least 45°. 4.

Shoulder it reversed, the hand grasping the barrels about their middle, the muzzle pointing forward and downward; this is perfectly admissible, but is the most awkward position of all to recover from. *Always carry a loaded gun at half-cock,* unless you are about to shoot. The best guns are now fitted with rebounding locks, having a device by which the hammer is thrown back to half-cock as soon as the blow is delivered on the firing-pin. This admirable device is a great safeguard, and is particularly eligible for breech-loaders, as the barrels may be unlocked and relocked without touching the hammers. Unless the lock fail, accidental discharge is impossible, except under these circumstances: (*a*) a direct blow on the nipple or pin; (*b*) catching of both hammer and trigger simultaneously, drawing back of the former and its release whilst the trigger is still held,—the chances against which are simply incalculable. Full-cock, ticklish as it seems, is safer than no-cock, when a tap on the hammer, or a slight catch and release of the hammer, may cause discharge. Never let the muzzle of a loaded gun point toward your own person for a single instant. Get your gun over fences, or into boats or carriages, before you get over or in yourself, or at any rate no later. Remove caps or cartridges on entering a house. Never aim a gun, loaded or not, at any object, unless you mean to press the trigger. Never put a loaded gun away long enough to forget whether it is loaded or not. Never leave a loaded gun to be found by others under circumstances reasonably presupposing it to be unloaded. Never put a gun where it can be knocked down by a dog or a child. Never imagine that there can be any excuse for putting away a breech-loader loaded under any circumstances. Never forget that the idiots who kill people because they "didn't know it was loaded," are perennial. Never forget that though a gunning accident may be sometimes interpreted (from a false standpoint) as a "dispensation of Providence," such dispensations happen oftenest to the careless.

To Clean a Gun properly requires some knowledge, more good temper, and most "elbow-grease"; it is dirty, disagreeable, inevitable work, which laziness, business, tiredness, indifference, and good taste will by turns tempt you to shirk. After a hunt you are tired, have your clothes to change, a meal to eat, a lot of birds to skin, a journal to write up. If you "sub-let" the contract, the chances are it is but half fulfilled; serve yourself, if you want to be well served. If you cannot find time for a regular cleaning, an intolerably foul gun may be made to do another day's work by swabbing for a few moments with a wet (not dripping) rag, and then with an oiled one. For the full wash use cold water first; it loosens dirt better than hot water. Set the barrels in a pail of water; wrap the end of the cleaning rod with tow or cloth, and

pump away till your arms ache. Change the rag or tow, and the water too, till they both stay clean for all the swabbing you can do. Then use boiling water till the barrels are well heated; wipe as dry as possible inside and out, and set them by a fire. Finish with a light oiling, inside and out; touch up all the metal about the stock, and polish the wood-work. *Do not remove the locks oftener than is necessary; every time they are taken out, something of the exquisite fitting that marks a good gun may be lost; as long as they work smoothly take it for granted they are all right.* To keep a gun well, under long disuse, it should have had a particularly thorough cleaning; the chambers should be packed with greasy tow; greased wads may be rammed at intervals along the barrels; or the barrels may be filled with melted tallow. Neat's-foot is recommended as the best easily procured oil; the porpoise-oil which is used by watchmakers is the very best; the oil made for use on sewing-machines is excellent; "olive" oil (made of lard) for table use answers the purpose. The quality of an oil may be improved by putting in it a few tacks, or scraps of zinc,—the oil expends its rusting capacity in oxidising the metal. Inferior oils get "sticky." One of the best preventives of rust is mercurial ("blue") ointment; it may be freely used. Kerosene will remove rust; but use it sparingly, for it "eats" sound metal too.

To Load a Gun effectively requires something more than knowledge of the facts that the powder should go in before the shot, and that each should have a wad atop. The most nearly universal fault is use of too much shot for the amount of powder; and the next, too much of both. The rule is *bulk for bulk* of powder and shot. If not exactly this, then rather less shot than powder. It is absurd to suppose, as some persons do who ought to know better, that the more shot in a gun the greater the chances of killing. The projectile force of a charge cannot possibly be greater than the *vis inertiæ* of the gun as held by the shooter. The explosion is manifested in all directions, and blows the shot in one way simply because it has no other escape. If the resistance in front of the powder were greater than elsewhere, the shot would not budge, but the gun would fly backward, or burst. This always reminds me of Lord Dundreary's famous conundrum—Why does a dog wag his tail? Because he is bigger than his tail; otherwise the tail would wag *him*. A gun shoots shot because the gun is the heavier; otherwise the shot would shoot the gun. Every unnecessary pellet is a pellet against you, not against the game. The experienced sportsman uses about one-third less shot than the tyro, with proportionally better result, other things being equal. As to powder, moreover, a gun can only burn just so much, and every grain blown out unburnt is wasted. No express directions for

absolute weight or measures of either powder or shot can be given; in fact, different guns take as their most effective charge such a variable amount of ammunition, that one of the first things you have to learn about your own arm is, its normal charge-gauge. Find out, by assiduous target practice, what absolute amounts (and to a slight degree, what relative proportion) of powder and shot are required to shoot the farthest and distribute the pellets most evenly. This practice, furthermore, will acquaint you with your gun's capacities in every respect. You should learn exactly what it will and what it will not do, so as to feel perfect confidence in your arm within a certain range, and to waste no shots in attempting miracles. Immoderate recoil is a pretty sure sign that the gun is overloaded, or otherwise wrongly charged; and all force of recoil is subtracted from the impulse of the shot. It is useless to ram powder very hard; two or three smart taps of the rod will suffice, and more will not increase the explosive force. On the shot the wad should simply be pressed close enough to fix the pellets immovably. These directions apply to the charging of metal or paper cartridges as well as to loading by the muzzle. The latter operation is rarely required, now that guns of every grade are made to break at the breech. Finally, let me impress upon you the expediency of *light loading* in your routine collecting. Three-fourths of your shots need not bring into action the gun's full powers of execution. *You will shoot more birds under than over thirty yards; not a few you must secure, if at all, at ten or fifteen yards; and your object is always to kill them with the least possible damage to the plumage.* I have, on particular occasions, loaded even down to *one third oz. of shot and one and a half dr. of powder.* There is *astonishing force compressed in a few grains of powder; an astonishing number of pellets in the smallest load of mustard-seed.*

To Shoot successfully is an art which may be acquired by practice, and can be learned only in the school of experience. No general directions will make you a good shot, any more than a proficient in music or painting. To tell you that in order to hit a bird you must point the gun at it and press the trigger, is like saying that to play on the fiddle you must shove the bow across the strings with one hand while you finger them with the other; in either case the result is the same, a noise, but neither music nor game. Nor is it possible for every one to become an artist in gunnery; a "crack-shot," like a poet, is born, not made. For myself, I make no pretensions to genius in that direction; for although I generally make fair bags, and have destroyed many thousand birds in my time, this is rather owing to some familiarity I have gained with the habits of birds, and a certain knack, acquired by long practice, of picking them out of trees and bushes, than to

skilful shooting from the sportsman's standpoint; in fact, if I cut down two or three birds on the wing without a miss I am working quite up to my average in that line. But any one not purblind or a "butter-fingers" can become a reasonably fair shot by practice, and do good collecting. It is not so hard, after all, to sight a gun correctly on an immovable object, and collecting differs from sporting proper in this, that comparatively few birds are shot on the wing. But I do not mean to imply that it requires less skill to collect successfully than to secure game; on the contrary, it is finer shooting, I think, to drop a warbler skipping about a tree-top than to stop a quail at full speed; while hitting a sparrow that springs from the grass at one's feet to flicker in sight a few seconds and disappear is the most difficult of all shooting. Besides, a crack shot, as understood, aims unconsciously, with mechanical accuracy and certitude of hitting; he simply wills, and the trained muscles obey without his superintendence, just as the fingers form letters with the pen in writing; whereas the collector must usually supervise his muscles all through the act and see that they mind. In spite of the proportion of snap-shots of all sorts you will have to take, your collecting shots, as a rule, are made with deliberate aim. There is much the same difference, on the whole, between the sportsman's work and the collector's, that there is between shot-gun and rifle practice, collecting being comparable to the latter. It is generally understood that the acme of skill with the two weapons is an incompatibility; and, certainly, the best shot is not always the best collector, even supposing the two to be on a par in their knowledge of birds' haunts and habits. Still, a hopelessly poor shot can only attain fair results by extraordinary diligence and perseverance. Certain principles of shooting may perhaps be reduced to words. Aim deliberately directly at an immovable object at fair range. Hold over a motionless object when far off, as the trajectory of the shot curves downward. Hold a little to one side of a stationary object when very near, preferring rather to take the chances of missing it with the peripheral pellets, than of hopelessly mutilating it with the main body of the charge. Fire at the first fair aim, without trying to improve what is good enough already. Never "pull" the trigger, but *press* it. Bear the shock of discharge without flinching. In shooting on the wing, fire the instant the heel of the gun taps your shoulder; you will miss at first, but by and by the birds will begin to drop, and you will have laid the foundation of good shooting, the knack of "covering" a bird unconsciously. The habit of "poking" after a bird on the wing is an almost incurable vice, and may keep you a poor shot all your life. (The collector's frequent necessity of poking after little birds in the bush is what so often hinders him from acquiring brilliant execution.) Aim

ahead of a flying bird—the calculation to be made varies, according to the distance of the object, its velocity, its course and the wind, from a few inches to several feet; practice will finally render it intuitive.

§ 2.—DOGS

A Good Dog is one of the most faithful, respectful, affectionate, and sensible of brutes; deference to such rare qualities demands a chapter, however brief. A trained dog is the indispensable servant of the sportsman in his pursuit of most kinds of game; but I trust I am guilty of no discourtesy to the noble animal, when I say that he is a luxury rather than a necessity to the collector—a pleasant companion, who knows almost everything except how to talk, who converses with his eyes and ears and tail, shares comforts and discomforts with equal alacrity, and occasionally makes himself useful. So far as a collector's work tallies with that of a sportsman, the dog is equally useful to both; but finding and telling of *game* aside, your dog's services are restricted to companionship and retrieving. He may, indeed, flush many sorts of birds for you; but he does it, if at all, at random, while capering about; for the brute intellect is limited after all, and cannot comprehend a naturalist. The best trained setter or pointer that ever marked a quail could not be made to understand what you are about, and it would ruin him for sporting purposes if he did. Take a well-bred dog out with you, and the chances are he will soon trot home in disgust at your performances with jack-sparrows and tomtits. It implies such a perversion of a good dog's instincts to make him really a useful servant of the collector, that I am half inclined to say nothing about retrieving, and tell you to make a companion of your dog, or let him alone. I was followed for several years by "the best dog I ever saw" (every one's gun, dog, and child is the best ever seen), and a first-rate retriever; yet I always preferred, when practicable, to pick up my own birds, rather than let a delicate plumage into a dog's mouth, and scolded away the poor brute so often, that she very properly returned the compliment, in the end, by retrieving just when she felt like it. However, we remained the best of friends. Any good setter, pointer, or spaniel, and some kinds of curs, may be trained to retrieve. The great point is to teach them not to "mouth" a bird; it may be accomplished by sticking pins in the ball with which their early lessons are taught. Such dogs are particularly useful in bringing birds out of the water, and in searching for them when lost. One point in training should never be neglected: teach a dog

what "to heel" means, and make him obey this command. A riotous brute is simply unendurable under any circumstances.

§ 3.—VARIOUS SUGGESTIONS AND DIRECTIONS FOR FIELD-WORK

To be a good Collector, and nothing more, is a small affair; great skill may be acquired in the art, without a single quality commanding respect. One of the most vulgar, brutal, and ignorant men I ever knew was a sharp collector and an excellent taxidermist. Collecting stands much in the same relation to ornithology that the useful and indispensable office of an apothecary bears to the duties of a physician. A field-naturalist is always more or less of a collector; the latter is sometimes found to know almost nothing of natural history worth knowing. The true ornithologist goes out to study birds alive and destroys some of them simply because that is the only way of learning their structure and technical characters. There is much more about a bird than can be discovered in its dead body,—how much more, then, than can be found out from its stuffed skin! In my humble opinion the man who only gathers birds, as a miser money, to swell his cabinet, and that other man who gloats, as miser-like, over the same hoard, both work on a plane far beneath where the enlightened naturalist stands. One looks at Nature, and never knows that she is beautiful; the other knows she is beautiful, as even a corpse may be; the naturalist catches her sentient expression, and knows how beautiful she is! I would have you to know and love her; for fairer mistress never swayed the heart of man. Aim high!—press on, and leave the half-way house of mere collectorship far behind in your pursuit of a delightful study, nor fancy the closet its goal.

Birds may be sought anywhere, at any time; they should be sought everywhere, at all times. Some come about your doorstep to tell their stories unasked. Others spring up before you as you stroll in the field, like the flowers that enticed the feet of Proserpine. Birds flit by as you measure the tired roadside, lending a tithe of their life to quicken your dusty steps. They disport overhead at hide-and-seek with the foliage as you loiter in the shade of the forest, and their music now answers the sigh of the tree-tops, now ripples an echo to the voice of the brook. But you will not always so pluck a thornless rose. Birds hedge themselves about with a bristling girdle of brier and bramble you cannot break; they build their tiny castles in the air surrounded by impassable moats, and the drawbridges are never down. They crown the

mountain-top you may lose your breath to climb; they sprinkle the desert where your parched lips may find no cooling draught; they fleck the snow-wreath when the nipping blast may make you turn your back; they breathe unharmed the pestilent vapours of the swamp that mean disease, if not death, for you; they outride the storm at sea that sends strong men to their last account. Where now will you look for birds?

And yet, as skilled labour is always most productive, so expert search yields more than random or blundering pursuit. The more varied the face of a country, the more various its birds. A place all plain, all marsh, all woodland, yields its particular set of birds, perhaps in profusion; but the kinds will be limited in number. It is of first importance to remember this, when you are so fortunate as to have choice of a collecting-ground; and it will guide your steps aright in a day's walk anywhere, for it will make you leave covert for open, wet for dry, high for low, and back again. Well-watered country is more fruitful of bird-life than desert or prairie; warm regions are more productive than cold ones. As a rule, variety and abundance of birds are in direct ratio to diversity and luxuriance of vegetation. Your most valuable as well as largest bags may be made in the regions most favoured botanically, up to the point where exuberance of plant-growth mechanically opposes your operations.

Search for particular Birds can only be well directed by a knowledge of their special haunts and habits, and is one of the mysteries of wood-craft to be solved by long experience and close observation. Here is where the true naturalist bears himself with conscious pride and strength, winning laurels that become him, and do honour to his calling. Where to find *game* ("game" is anything that vulgar people do not ridicule you for shooting) of all the kinds we have in this country has been so often and so minutely detailed in sporting-works that it need not be here enlarged upon, especially since, being the best known, game-birds are the least valuable of ornithological material. Most large or otherwise conspicuous birds have very special haunts that may be soon learned; and as a rule such rank next after game in ornithological disesteem. Birds of prey are an exception to these statements; they range everywhere, and most of them are worth securing. Hawks will unwittingly fly in your way oftener than they will allow you to approach them when perched: be ready for them. Owls will be startled out of their retreats in thick bushes, dense foliage, and hollow trees, in the daytime; if hunting them at night, good aim in the dark may be taken by rubbing a wet lucifer match on the sight of the gun, causing a momentary glimmer. Large and small waders are to be found by any water's edge, in open marshes, and often on dry

plains; the herons more particularly in heavy bogs and dense swamps. Under cover, waders are oftenest approached by stealth; in the open, by strategy; but most of the smaller kinds require the exercise of no special precautions. Swimming-birds, aside from water-fowl (as the "game" kinds are called), are generally shot from a boat, as they fly past; but at their breeding-places many kinds that congregate in vast numbers are readily reached. There is a knack of shooting loons and grebes on the water; if they are to be reached at all by the shot it will be by aiming not directly at them but at the water just in front of them. They do not go under just where they float, but kick up behind like a jumping-jack and plunge forward. Rails and several kinds of sparrows are confined to reedy marshes. But why prolong such desultory remarks? Little can be said to the point without at least a miniature treatise on ornithology; and I have not yet even alluded to the diversified host of small insectivorous and granivorous birds that fill our woods and fields. The very existence of most of these is unknown to all but the initiated; yet they include the treasures of the ornithologist. Some are plain and humble, others are among the most beautiful objects in nature; but most agree in being *small*, and therefore liable to be overlooked. The sum of my advice about them must be brief. Get over as much ground, both wooded and open, as you can thoroughly examine in a day's tramp, and go out as many days as you can. It is not always necessary, however, to keep on the tramp, especially during the migration of the restless insectivorous species. One may often shoot for hours without moving more than a few yards, by selecting a favourable locality and allowing the birds to come to him as they pass in varied troops through the low woodlands or swampy thickets. Keep your eyes and ears wide open. Look out for every rustling leaf and swaying twig and bending blade of grass. Hearken to every note, however faint; when there is no sound, listen for a chirp. Habitually move as noiselessly as possible. Keep your gun always ready. Improve every opportunity of studying a bird you do not wish to destroy; you may often make observations more valuable than the specimen. Let this be the rule with all birds you recognise. But I fear I must tell you to shoot an unknown bird on sight; it may give you the slip in a moment and a prize may be lost. One of the most fascinating things about field-work is its uncertainty; you never know what's in store for you as you start out; you never can tell what will happen next; surprises are always in order, and excitement is continually whetted on the chances of the varied chase.

For myself, the time is past, happily or not, when every bird was an agreeable surprise, for dewdrops do not last all day; but I have never yet walked in the woods without learning something

pleasant that I did not know before. I should consider a bird new to science ample reward for a month's steady work; one bird new to a locality would repay a week's search; a day is happily spent that shows me any bird that I never saw alive before. How then can you, with so much before you, keep out of the woods another minute?

All Times are good times to go a-shooting; but some are better than others. (*a*) *Time of year.* In all temperate latitudes, spring and fall—periods of migration with most birds—are the most profitable seasons for collecting. Not only are birds then most numerous, both as species and as individuals, and most active, so as to be the more readily found, but they include a far larger proportion of rare and valuable kinds. In every locality in this country the periodical visitants outnumber the permanent residents; in most regions the number of regular migrants, that simply pass through in the spring and fall, equals or exceeds that of either of the sets of species that come from the south in spring to breed during the summer, or from the north to spend the winter. Far north, of course, on or near the limit of the vernal migration, where there are few if any migrants, and where the winter birds are extremely few, nearly all the bird-fauna is composed of "summer visitants"; far south the reverse is somewhat the case, though with many qualifications. Between these extremes, what is conventionally known as "a season" means the period of the vernal or autumnal migration. Look out, then, for "the season," and work all through it at a rate you could not possibly sustain the year around. (*b*) *Time of day.* Early in the morning and late in the afternoon are the best times for birds. There is a mysterious something in these diurnal crises that sets bird-life astir, over and above what is explainable by the simple fact that they are the transition periods from repose to activity, or the reverse. Subtle meteorological changes occur; various delicate instruments used in physicists' researches are sometimes inexplicably disturbed; diseases have often their turning point for better or worse; people are apt to be born or die; and the susceptible organisms of birds manifest various excitements. Whatever the operative influence, the fact is, birds are particularly lively at such hours. In the dark they rest—most of them do; at noonday, again, they are comparatively still; between these times they are passing to or from their feeding grounds or roosting places; they are foraging for food, they are singing; at any rate, they are in motion. Many migratory birds (among them warblers, etc.) perform their journeys by night; just at daybreak they may be seen to descend from the upper regions, rest a while, and then move about briskly, singing and searching for food. Their meal taken, they recuperate by resting till towards evening; feed again and are off for the night. If you have had some experience,

don't you remember what a fine spurt you made early that morning? —how many unexpected shots offered as you trudged home belated that evening? Now I am no fowl, and have no desire to adopt the habits of the hen-yard; I have my opinion of those who like the world before it is aired; I think it served the worm right for getting up, when caught by the early bird; nevertheless I go shooting betimes in the morning, and would walk all night to find a rare bird at daylight. (*c*) *Weather.* It rarely occurs in this country that either heat or cold is unendurably severe; but extremes of temperature are unfavourable, for two reasons: they both occasion great personal discomfort; and in one extreme only a few hardy birds will be found, while in the other most birds are languid, disposed to seek shelter, and therefore less likely to be found. A still, cloudy day of moderate temperature offers as a rule the best chance; among other reasons, there is no sun to blind the eyes, as always occurs on a bright day in one direction, particularly when the sun is low. While a bright day has its good influence in setting many birds astir, some others are most easily approached in heavy or falling weather. Some kinds are more likely to be secured during a light snowfall, or after a storm. Singular as it may seem, a thoroughly wet day offers some peculiar inducements to the collector. I cannot well specify them, but I heartily indorse a remark John Cassin once made to me: "I like," said he, "to go shooting in the rain sometimes; there are some curious things to be learned about birds when the trees are dripping; things, too, that have not yet found their way into the books."

How many Birds of the Same Kind do you want?—*All you can get*—with some reasonable limitations; say fifty or a hundred of any but the most abundant and widely diffused species. You may often be provoked with your friend for speaking of some bird he shot, but did not bring you, because, he says, "Why, you've got one like that!" Birdskins are capital; capital unemployed may be useless, but can never be worthless. Birdskins are a medium of exchange among ornithologists the world over; they represent value—money value and scientific value. If you have more of one kind than you can use, exchange with some one for species you lack; both parties to the transaction are equally benefited. Let me bring this matter under several heads. (*a*) Your own series of skins of any species is incomplete until it contains at least one example of each sex, of every normal state of plumage, and every normal transition stage of plumage, and further illustrates the principal abnormal variations in size, form, and colour to which the species may be subject; I will even add that every different faunal area the bird is known to inhabit should be represented by a specimen, particularly if there be anything exceptional in the

geographical distribution of the species. Any additional specimens to all such are your only "duplicates," properly speaking. (*b*) Birds vary so much in their size, form, and colouring, that a "specific character" can only be precisely determined from examination of a large number of specimens, shot at different times, in different places; still less can the "limits of variation" in these respects be settled without ample materials. (*c*) The rarity of any bird is an arbitrary and fluctuating consideration, because in the nature of the case there can be no natural unit of comparison, nor standard of appreciation. It may be said, in general terms, no bird is actually "rare." With a few possible exceptions, as in the cases of birds occupying extraordinarily limited areas, like some of the birds-of-paradise, or about to become extinct, like the pied duck,[1] enough birds of all kinds exist to overstock every public and private collection in the world, without sensible diminution of their numbers. "Rarity" or the reverse is only predicable upon the accidental (so to speak) circumstances that throw, or tend to throw, specimens into naturalists' hands. *Accessibility* is the variable element in every case. The fulmar petrel [2] is said (on what authority I know not) to exceed any other bird in its aggregate of individuals; how do the skins of that bird you have handled compare in number with specimens you have seen of the "rare" warbler of your own vicinity? All birds are common somewhere at some season: the point is, have collectors been there at the time? Moreover, even the arbitrary appreciation of "rarity" is fluctuating, and may change at any time; long-sought and highly-prized birds are liable to appear suddenly in great numbers in places that knew them not before; a single heavy invoice of a bird from some distant or little-explored region may at once stock the market, and depreciate the current value of the species to almost nothing. For example, Baird's bunting[3] and Sprague's lark[4] remained for thirty years among special desiderata, only one specimen of the former and two or three of the latter being known. Yet they are two of the most abundant birds of Dakota, where in 1873 I took as many of both as I desired; and specimens enough have lately been secured to stock all the leading museums of both Europe and America. (*d*) Some practical deductions are to be made from these premisses. Your object is to make yourself acquainted with all the birds of your vicinity, and to preserve a complete suite of specimens of every species. Begin by shooting every bird you can, coupling this sad destruction, however, with the closest observations upon habits. You will very soon fill your series of a few kinds, that you find almost everywhere, almost daily. Then if you are in a

[1] *Camptolæmus labradorius.*

[2] *Fulmarus glacialis.*

[3] *Passerculus* (*Centronyx*) *bairdi.*

[4] *Anthus* (*Neocorys*) *spraguei.*

region the ornithology of which is well known, at once stop killing these common birds—they are in every collection. Keep an eye on them, studying them always, but turn your actual pursuit into other channels, until in this way, gradually eliminating the undesirables, you exhaust the bird-fauna as far as possible (you will not *quite* exhaust it—at least for many years). But if you are in a new or little-known locality, I had almost said the very reverse course is the best. The chances are that the most abundant and characteristic birds there are "rare" in collections. Many a bird's range is quite restricted: you may happen to be just at its metropolis; seize the opportunity, and get good store,—yes, up to fifty or a hundred; all you can spare will be thankfully received by those who have none. Quite as likely, birds that are scarce just where you happen to be, are so only because you are on the edge of their habitat, and are plentiful in more accessible regions. But, rare or not, it is always a point to determine the exact geographical distribution of a species; and this is fixed best by having specimens to tell each its own tale, from as many different and widely-separated localities as possible. This alone warrants procuring one or more specimens in every locality; the commonest bird acquires a certain value if it be captured away from its ordinary range. But let all your justifiable destruction of birds be tempered with mercy; your humanity will be continually shocked with the havoc you work, and should never permit you to take life wantonly. Never shoot a bird you do not fully intend to preserve, or to utilise in some proper way. Bird-life is too beautiful a thing to destroy to no purpose; too sacred a thing, like all life, to be sacrificed, unless the tribute is hallowed by worthiness of motive. "Not a sparrow falleth to the ground without His notice."

I should not neglect to speak particularly of the care to be taken to secure full suites of *females*. Most miscellaneous collections contain four or more males to every female—a disproportion that should be as far reduced as possible. The reason for this disparity is obvious: females are usually more shy and retiring in disposition, and less frequently noticed; while their smaller size and plainer plumage, as a rule, further favour their concealment. The difference in colouring is greatest among those groups where the males are most richly clad, and the shyness of the mother birds is most marked during the breeding season, just when the males, full of song, and in their nuptial attire, become most conspicuous. It is often worth while to neglect the gay Benedicts, to trace out and secure the plainer but not less interesting females. This pursuit, moreover, often leads to discovery of the nests and eggs,—an important consideration. Although both sexes are generally found together when breeding, and mixing indiscriminately at other seasons, they often go in sepa-

rate flocks, and often migrate independently of each other; in this case the males usually in advance. Towards the end of the passage of some warblers, for instance, we may get almost nothing but females, all our specimens of a few days before having been males. The notable exceptions to the rule of smaller size of the female are among rapacious birds and many waders, though in these last the disparity is not so marked. I only recall one instance, among English birds, of the female being more richly coloured than the male—the phalaropes. When the sexes are notably different in adult life, the *young* of both sexes usually resemble the adult female, the young males gradually assuming their distinctive characters. When the adults of both sexes are alike, the young commonly differ from them.

In the same connection I wish to urge a point, the importance of which is often overlooked; it is our practical interpretation of the adage, "a bird in the hand is worth two in the bush." Always keep the first specimen you secure of a species till you get another, no matter how common the species, how poor the specimen, or how certain you may feel of getting others. Your most reasonable calculations may come to naught, from a variety of circumstances, and any specimen is better than no specimen, on general principles. And in general, do not, if you can help it, discard any specimen in the field. No tyro can tell what will prove valuable and what not; while even the expert may regret to find that a point comes up which a specimen he injudiciously discarded might have determined. Let a collection be "weeded out," if at all, only after deliberate and mature examination, when the scientific results it affords have been elaborated by a competent ornithologist; and even then, the refuse (with certain limitations) had better be put where it will do some good, than be destroyed utterly. If forced to reduce bulk, owing to limited facilities for transportation in the field (as too often happens), throw away according to size, other things being equal. Given only so many cubic inches or feet, eliminate the few large birds which take up the space that would contain fifty or a hundred different little ones. If you have a fine large eagle or pelican, for instance, throw it away first, and follow it with your ducks, geese, etc. In this way, the bulk of a large miscellaneous collection may be reduced one-half, perhaps, with very little depreciation of its actual value. The same principle may be extended to other collections in natural history (excepting fossils, which are always weighty, if not also bulky); very few birdskins, indeed, being as valuable contributions to science as, for example, a vial of insects that occupies no more room may prove to be.

What is "A Good Day's Work"?—Fifty birds shot, their skins preserved, and observations recorded, is a *very* good day's work; it

is sharp practice, even when birds are plentiful. I never knew a person to average anywhere near it; even during the "season" such work cannot possibly be sustained. You may, of course, by a murderous discharge into a flock, get a hundred or more in a moment; but I refer to collecting a fair variety of birds. You will do very well if you average a dozen a day during the seasons. I doubt whether any collector ever averaged as many the year around; it would be over four thousand specimens annually. The greatest number I ever procured and prepared in one day was forty, and I have not often gone over twenty. Even when collecting regularly and assiduously, I am satisfied to average a dozen a day during the migrations, and one-third or one-fourth as many the rest of the year. Probably this implies the shooting of about one in five not skinned for various reasons, as mutilation, decay, or want of time.

Approaching Birds.—There is little if any trouble in getting near enough to shoot most birds. With notable exceptions, they are harder to see when near enough, or to hit when seen; particularly small birds that are almost incessantly in motion. As a rule—and a curious one it is—difficulty of approach is in direct ratio to the *size* of the bird; it is perhaps because large conspicuous birds are objects of more general pursuit than the little ones you ordinarily search for. The qualities that birds possess for self-preservation may be called *wariness* in large birds, *shyness* in small ones. The former make off knowingly from a suspicious object; the latter fly from anything that is strange to them, be it dangerous or not. This is strikingly illustrated in the behaviour of small birds in the wilderness, as contrasted with their actions about towns; they are more timid under the former circumstances than when grown accustomed to the presence of man. It is just the reverse with a hawk or raven, for instance; in populous districts they spend much of their time in trying to save their skins, while in a new country they have not learned, like Indians, that a white man is "mighty uncertain." In stealing on a shy bird, you will of course take advantage of any cover that may offer, as inequalities of the ground, thick bushes, the trunks of trees; and it is often worth while to make a considerable détour to secure unobserved approach. I think that birds are more likely, as a rule, to be frightened away by the movements of the collector, than by his simple presence, however near, and that they are more afraid of noise than of mere motion. Crackling of twigs and rustling of leaves are sharp sounds, though not loud ones; you may have sometimes been surprised to find how distinctly you could hear the movements of a horse or cow in underbrush at some distance. Birds have sharp ears for such sounds. Form a habit of stealthy movement; it tells, in the long run, in comparison with lumbering tread. There are no special

precautions to be taken in shooting through high open forest; you have only to saunter along with your eyes in the tree-tops. It is ordinarily the easiest and on the whole the most remunerative path of the collector. In traversing fields and meadows move briskly, your principal object being to flush birds out of the grass; and as most of your shots will be snap ones, keep in readiness for instant action. Excellent and varied shooting is to be had along the hedgerows, and in the rank herbage that fringes fences. It is best to keep at a little distance, yet near enough to arouse all the birds as you pass; you may catch them on wing, or pick them off just as they settle after a short flight. In this shooting, two persons, one on each side, can together do more than twice as much work as one. Thickets and tangled undergrowth are favourite resorts of many birds; but when very close, or, as often happens, over miry ground, they are hard places to shoot in. As you come thrashing through the brush, the little inhabitants are scared into deeper recesses; but if you keep still a few minutes in some favourable spot, they are reassured, and will often come back to take a peep at you. A good deal of standing still will repay you at such times; needless to add, you cannot be too lightly loaded for such shooting, when birds are mostly out of sight if a dozen yards off. When yourself concealed in a thicket, and no birds appear, you can often call numbers about you by a simple artifice. Apply the back of your hand to your slightly parted lips, and suck in air; it makes a nondescript screeping noise, variable in intonation at your whim, and some of the sounds resemble the cries of a wounded bird, or a young one in distress. It wakes up the whole neighbourhood, and sometimes puts certain birds almost beside themselves, particularly in the breeding season. Torturing a wounded bird to make it scream in agony accomplishes the same result, but of course is only permissible under great exigency. In penetrating swamps and marshes, the best advice I can give you is to tell you to get along the best way you can. Shooting on perfectly open ground offers much the same case; you must be left to your own devices. I will say, however, you can ride on horseback, or even in a buggy, nearer birds than they will allow you to walk up to them. Sportsmen take advantage of this to get within a shot of the upland plover, usually a very wary bird in populous districts; I have driven right into a flock of wild geese; in California they often train a bullock to graze gradually up to geese, the gunner being hidden by its body. There is one trick worth knowing; it is not to let a bird that has seen you know by your action that you have seen *it*, but to keep on unconcernedly, gradually sidling nearer. I have secured many hawks in this way, when the bird would have flown off at the first step of direct approach. Number-

less other little arts will come to you as your wood-craft matures.

Recovering Birds.—It is not always that you secure the birds you kill; you may not be able to find them, or you may see them lying, perhaps but a few feet off, in a spot practically inaccessible. Under such circumstances a retriever does excellent service, as already hinted; he is equally useful when a bird properly "marked down" is not found there, having fluttered or run away and hidden elsewhere. The most difficult of all places to find birds is among reeds, the sameness of which makes it almost impossible to rediscover a spot whence the eye has once wandered, while the peculiar growth allows birds to slip far down out of sight. In rank grass or weeds, when you have walked up with your eye fixed on the spot where the bird seemed to fall, yet failed to discover it, drop your cap or handkerchief for a mark, and hunt around it as a centre, in enlarging circles. In thickets, make a bee-line for the spot, if possible keeping your eye on the spray from which the bird fell, and not forgetting where you stood on firing; you may require to come back to the spot and take a new departure. You will not seldom see a bird just shot at fly off as if unharmed, when really it will drop dead in a few moments. In all cases, therefore, when the bird does not drop at the shot, follow it with your eyes as far as you can; if you see it finally drop, or even flutter languidly downward, mark it on the principles just mentioned, and go in search. Make every endeavour to secure wounded birds, on the score of humanity; they should not be left to pine away and die in lingering misery if it can possibly be avoided.

Killing Wounded Birds.—You will often recover winged birds, as full of life as before the bone was broken; and others too grievously hurt to fly, yet far from death. Your object is to kill them as quickly and painlessly as possible, without injuring the plumage. This is to be accomplished, with all small birds, by suffocation. The respiration and circulation of birds is very active, and most of them die in a few moments if the lungs are so compressed that they cannot breathe. Squeeze the bird tightly across the chest, under the wings, thumb on one side, middle finger on the other, forefinger pressed in the hollow at the root of the neck, between the forks of the merrythought. Press firmly, hard enough to fix the chest immovably and compress the lungs, but not to break in the ribs. The bird will make vigorous but ineffectual efforts to breathe, when the muscles will contract spasmodically; but in a moment more, the system relaxes with a painful shiver, light fades from the eyes, and the lids close. I assure you, it will make you wince the first few times; you had better hold the poor creature behind you. You can tell by its limp feel and motionlessness when

it is dead, without watching the sad struggle. Large birds cannot be dealt with in this way; I would as soon attempt to throttle a dog as a loon, for instance, upon which all the pressure you can give makes no sensible impression. A winged hawk, again, will throw itself on its back as you come up, and show such good fight with beak and talons, that you may be quite severely scratched in the encounter: meanwhile the struggling bird may be bespattering its plumage with blood. In such a case—in any case of a large bird making decided resistance—I think it best to step back a few paces and settle the matter with a light charge of mustard-seed. Any large bird once secured may be speedily despatched by stabbing to the heart with some slender instrument thrust in under the wing—care must be taken too about the bleeding; or, it may be instantly killed by piercing the brain with a knife introduced into the mouth and driven upward and obliquely backward from the palate. The latter method is preferable, as it leaves no outward sign and causes no bleeding to speak of. With your thumb, you may indent the back part of a small bird's skull so as to compress the cerebellum, which causes instant death. It is useless to compress the windpipe of a bird whose wing is broken near the shoulder, for the bone is hollow, and the bird can breathe through it.

Handling Bleeding Birds.—Bleeding depends altogether upon what part or organ is wounded; but, other things being equal, violence of the hæmorrhage is usually in direct proportion to the size of the shot-hole; when mustard-seed is used it is ordinarily very trifling, if it occur at all. Blood flows oftener from the orifice of exit of a shot, than from the wound of entrance, for the latter is usually plugged with a little wad of feathers. Bleeding from the mouth or nostrils is the rule when the lungs are wounded. When it occurs, hold up the bird by the feet, and let it drip; a general squeeze of the body in that position will facilitate the drainage. In general, hold a bird so that a bleeding place is most dependent; then, pressure about the part will help the flow. A "gob" of blood, which is simply a forming clot, on the plumage may often be dexterously flipped almost clean away with a snap of the finger. It is first-rate practice to take cotton and forceps into the field to plug up shot-holes, and stop the mouth and nostrils and vent on the spot. I follow the custom of the books in recommending this, but I suspect that only a few of the most leisurely and elegant collectors do so habitually. Shot-holes may be found by gently raising the feathers, or blowing them aside; you can of course get only a tiny plug into the wound itself, but it should be one end of a sizable pledget, the rest lying fluffy among the feathers. In stopping the mouth or vent, ram the fluff of cotton entirely inside. You cannot conveniently stop up the nostrils of small birds sepa-

rately; but take a light cylinder of cotton, lay it transversely across the base of the upper mandible, closely covering the nostrils, and *confine it there by tucking each end tightly into the corner of the mouth.* In default of such nice fixing as this, a pinch of dry loam pressed on a bleeding spot will plaster itself there and stop further mischief. Never try to *wipe off* fresh blood that has already wetted the plumage; you will only make matters worse. Let it dry on, and then—but the treatment of blood-stains, and other soilings of plumage, is given beyond.

Carrying Birds Home Safe.—Suppose you have secured a fine specimen, very likely without a soiled or ruffled feather; your next care will be to keep it so till you are ready to skin it. But if you pocket or bag it directly, it will be a sorry-looking object before you get home. Each specimen must be separately cared for, by wrapping in stout paper; writing paper is as good as any, if not the best. It will repay you to prepare a stock of paper before starting out; your most convenient sizes are those of a half-sheet of note, of letter, and of cap respectively. Either take these, or fold and cut newspaper to correspond. Plenty of paper will go in the breast pockets of the shooting coat. Make a "cornucopia,"—the simplest thing in the world, but, like tying a particular knot, hard to explain. Setting the wings closely, adjusting disturbed feathers, and seeing that the bill points straight forward, thrust the bird head-first into one of these paper cones, till it will go no farther, being bound by the bulge of the breast. Let the cone be large enough for the open end to fold over or pinch together entirely beyond the tail. Be particular not to crumple or bend the tail-feathers. Lay the paper cases in the game bag or great pocket so that they very nearly run parallel and lie horizontal; they will carry better than if thrown in at random. Avoid overcrowding the packages, as far as is reasonably practicable; moderate pressure will do no harm, but if great it may make birds bleed afresh, or cause the fluids of a wounded intestine to ooze out and soak the plumage of the belly,—a very bad accident indeed. For similar obvious reasons, do not put a large heavy bird on top of a lot of little ones; I would sooner sling a hawk or heron over my shoulder, or carry it by hand. If it goes in the bag, see that it gets to the bottom. Avoid putting birds in pockets that are close about your person; they are almost always unduly pressed, and may gain enough additional warmth from your body to make them begin to decompose before you are ready to skin them. Handle birds no more than is necessary, especially white-plumaged ones; ten to one your hands are powder-begrimed: and besides, even the warmth and moisture of your palms may tend to injure a delicate feathering. Ordinarily pick up a bird by the feet or bill; as you need

both hands to make the cornucopia, let the specimen dangle by the *toes from your teeth* while you are so employed. In catching at a wounded bird, aim to cover it entirely with your hand; but whatever you do, never seize it by the tail, which then will often be left in your hands for your pains. Never grasp wing-tips or tail-feathers; these large flat quills would get a peculiar crimping all along the webs, very difficult to efface. Finally, I would add, there is a certain knack or art in manipulating, either of a dead bird or a birdskin, by which you may handle it with seeming carelessness and perfect impunity; whilst the most gingerly fingering of an inexperienced person will leave its rude trace. You will naturally acquire the correct touch; but it can be neither taught nor described. While the ordinary run of land-birds will be brought home in good order by the foregoing method, some require special precautions. I refer to sea-birds, such as gulls, terns, petrels, etc., shot from a boat. In the first place, the plumage of most of them is, in part at least, white and of exquisite purity. Then, fish-eating birds usually vomit and purge when shot. They are necessarily fished all dripping from the water. They are too large for pocketing. If you put them on the thwarts or elsewhere about the boat, they usually fall off, or are knocked off, into the bilge water; if you stow them in the cubby-hole, they will assuredly soil by mutual pressure, or by rolling about. It will repay you to pick them from the water by the bill, and shake off all the water you can; hold them up, or let some one do it, till they are tolerably dry; plug the mouth, nostrils, and vent, if not also shot-holes; wrap each one separately in a cloth (not paper) or a mass of tow, and pack steadily in a covered box or basket taken on board for this purpose. With such precautions as these, birds most liable to be soiled reach the skinning-table in perfect order; and your care will afterward transform them into specimens without spot or blemish.

§ 4.—HYGIENE OF COLLECTORSHIP

It is unnecessary to speak of the Healthfulness of a pursuit that, like the collector's occupation, demands regular bodily exercise, and at the same time stimulates the mind by supplying an object, thus calling the whole system into exhilarating action. Yet collecting has its perils, not to be overlooked if we would adequately guard against them, as fortunately we may, in most cases, by simple precautions. The dangers of taxidermy itself are elsewhere noticed; but, besides these, the collector is exposed to vicissitudes of the weather, may endure great fatigue, may breathe miasm, and may be mechanically injured.

Accidents from the Gun have been already noticed; a few special rules will render others little liable to occur. The secret of safe *climbing* is never to relax one hold until another is secured; it is equally applicable to scrambling over rocks, a particularly difficult thing to do safely with a loaded gun. Test rotten, slippery, or otherwise suspicious holds before trusting them. In lifting the body up anywhere, keep the mouth shut, breathe through the nostrils, and go slowly. In *swimming*, waste no strength unnecessarily in trying to stem a current; yield partly, and land obliquely lower down; if exhausted, float; the slightest motion of the hands will ordinarily keep the face above water; and in any event keep your wits collected. In fording deeply, a heavy stone will strengthen your position. Never sail a boat experimentally; if you are no sailor, take one with you or stay on land. In crossing a high, narrow footpath, never look lower than your feet; the muscles will work true if not confused with faltering instructions from a giddy brain. On soft ground, see what, if anything, has preceded you; large hoof-marks generally mean that the way is safe; if none are found, inquire for yourself before going on. Quicksand is the most treacherous, because far more dangerous than it looks. Cattle-paths, however erratic, commonly prove the surest way out of a difficult place, whether of uncertain footing or dense undergrowth.

Miasm.—Unguarded exposure in malarious regions usually entails sickness, often preventable, however, by due precautions. It is worth knowing, in the first place, that miasmatic poison is most powerful between sunset and sunrise; more exactly, from the damp of the evening until night-vapours are dissipated; we may be out in the daytime with comparative impunity, where to pass a night would be almost certain disease. If forced to camp out, seek the highest and driest spot, put a good fire on the swamp side, and also, if possible, let trees intervene. Never go out on an empty stomach; just a cup of coffee and a crust may make a decided difference. Meet the earliest unfavourable symptoms with quinine; I should rather say, if unacclimated, anticipate them with this invaluable agent. Endeavour to maintain high health of all functions by the natural means of regularity and temperance in diet, exercise, and repose.

"Taking Cold."—This vague "household word" indicates one or more of a long varied train of unpleasant affections, nearly always traceable to one or the other of only two causes: *sudden change* of temperature, and *unequal distribution* of temperature on the surface of the person. No extremes of heat or cold can alone effect this result; persons frozen to death do not "take cold" during the process. But if a part of the body be rapidly cooled, as by evaporation from a wet article of clothing, or by sitting in a

draught of air, the rest of the surface remaining at an ordinary temperature; or if the temperature of the whole be suddenly changed by going out into the cold, or by coming into a warm room, there is much liability of trouble. There is an old saying—

When the air comes through a hole
Say your prayers to save your soul;

and I should think almost any one could get "a cold" with a spoonful of water on the wrist held to a key-hole. Singular as it may seem, sudden warming when cold is more dangerous than the reverse; every one has noticed how soon the handkerchief is required on entering a heated room on a cold day. Frost-bite offers an extreme illustration of this. As the Irishman said on picking himself up, it was not the fall, but stopping so quickly, that hurt him; it is not the gradual lowering of the temperature to the freezing-point, but its subsequent sudden elevation, that devitalises the tissue. This is why rubbing with snow, or bathing in cold water, is required to restore safely a frozen part; the arrested circulation must be very gradually re-established, or inflammation, perhaps mortification, ensues. General precautions against taking cold are almost self-evident in this light. There is ordinarily little if any danger to be apprehended from wet clothes, so long as exercise is kept up; for the glow compensates for the extra cooling by evaporation. Nor is a complete drenching more likely to be injurious than wetting of one part. But never sit still wet; and in changing rub the body dry. There is a general tendency, springing from fatigue, indolence, or indifference, to neglect damp feet; that is to say, to dry them by the fire; but this process is tedious and uncertain. I would say especially, off with the muddy boots and sodden socks at once; dry stockings and slippers, after a hunt, may make just the difference of your being able to go out again or never. Take care never to check perspiration; during this process, the body is in a somewhat critical condition, and sudden arrest of the function may result disastrously, even fatally. One part of the business of perspiration is to equalise bodily temperature, and it must not be interfered with. The secret of much that might be said about *bathing* when heated lies here. A person overheated, panting it may be, with throbbing temples, and a *dry* skin, is in danger partly because the natural cooling by evaporation from the skin is denied, and this condition is sometimes not far from a sunstroke. Under these circumstances, a person of fairly good constitution may plunge into the water with impunity, even with benefit. But if the body be already cooling by sweating, rapid abstraction of heat from the surface may cause internal congestion, never unattended with danger. Drinking ice-water

offers a somewhat parallel case; even on stooping to drink at the brook, when flushed with heat, it is well to bathe the face and hands first, and to taste the water before a full draught. It is a well-known excellent rule, not to bathe immediately after a full meal; because during digestion the organs concerned are comparatively engorged, and any sudden disturbance of the circulation may be disastrous. The imperative necessity of resisting drowsiness under extreme cold requires no comment. In walking under a hot sun, the head may be sensibly protected by green leaves or grass in the hat; they may be advantageously moistened, but not enough to drip about the ears. Under such circumstances the slightest giddiness, dimness of sight, or confusion of ideas, should be taken as a warning of possible sunstroke, instantly demanding rest and shelter.

Hunger and Fatigue are more closely related than they might seem to be; one is a sign that the fuel is out, and the other asks for it. Extreme fatigue, indeed, destroys appetite; this simply means, temporary incapacity for digestion. But even far short of this, food is more easily digested and better relished after a little preparation of the furnace. On coming home tired, it is much better to make a leisurely and reasonably nice toilet than to eat at once, or to sit still thinking how tired you are; after a change and a wash you will feel like a "new man," and go to table in capital state. Whatever dietetic irregularities a high state of civilisation may demand or render practicable, a normally healthy person is inconvenienced almost as soon as his regular meal-time passes without food; a few can work comfortably or profitably fasting over six or eight hours. Eat before starting; if for a day's tramp, take a lunch; the most frugal meal will appease if it do not satisfy hunger, and so postpone its urgency. As a small scrap of practical wisdom, I would add, keep the remnants of the lunch, if there are any; for you cannot always be sure of getting in to supper.

Stimulation.—When cold, fatigued, depressed in mind, and on other occasions, you may feel inclined to resort to artificial stimulus. Respecting this many-sided theme I have a few words to offer of direct bearing on the collector's case. It should be clearly understood in the first place that a stimulant confers no strength whatever; it simply calls the powers that be into increased action at their own expense. Seeking real strength in stimulus is as wise as an attempt to lift yourself up by the boot-straps. You may gather yourself to leap the ditch and you clear it; but no such muscular energy can be sustained; exhaustion speedily renders further expenditure impossible. But now suppose a very powerful mental impression be made, say the circumstance of a succession of ditches in front, and a mad dog behind; if the stimulus of terror be suffi-

ciently strong, you may leap on till you drop senseless. Alcoholic stimulus is a parallel case, and is not seldom pushed to the same extreme. Under its influence you never can tell when you *are* tired; the expenditure goes on, indeed, with unnatural rapidity, only it is not felt at the time; but the upshot is you have all the original fatigue to endure and to recover from, *plus* the fatigue resulting from over-excitation of the system. Taken as a fortification against cold, alcohol is as unsatisfactory as a remedy for fatigue. Insensibility to cold does not imply protection. The fact is the exposure is greater than before; the circulation and respiration being hurried, the waste is greater, and as sound fuel cannot be immediately supplied, the temperature of the body is soon lowered. The transient warmth and glow over, the system has both cold *and* depression to endure; there is no use in borrowing from yourself and fancying you are richer. Secondly, the value of any stimulus (except in a few exigencies of disease or injury) is in proportion, *not to the intensity*, but to the equableness and durability of its effect. This is one reason why tea, coffee, and articles of corresponding qualities are preferable to alcoholic drinks; they work so smoothly that their effect is often unnoticed, and they "stay by" well; the friction of alcohol is tremendous in comparison. A glass of grog may help a veteran over the fence, but no one, young or old, can shoot all day on liquor. I have had so much experience in the use of tobacco as a mild stimulant that I am probably no impartial judge of its merits: I will simply say I do not use it in the field, because it indisposes to muscular activity, and favours reflection when observation is required; and because temporary abstinence provokes the morbid appetite and renders the weed more grateful afterwards. Thirdly, undue excitation of any physical function is followed by corresponding depression, on the simple principle that action and reaction are equal; and the balance of health turns too easily to be wilfully disturbed. Stimulation is a draft upon vital capital, when interest alone should suffice; it may be needed at times to bridge a chasm, but habitual living beyond vital income infallibly entails bankruptcy in health. The use of alcohol in health seems practically restricted to purposes of sensuous gratification on the part of those prepared to pay a round price for this luxury. The three golden rules here are,—never drink before breakfast, never drink alone, and never drink bad liquor; their observance may make even the abuse of alcohol tolerable. Serious objections, for a naturalist at least, are that science, viewed through a drinking-glass, seems distant and uncertain, while the pleasure of drinking is immediate and unquestionable; and that intemperance, being an attempt to defy certain physical laws, is therefore eminently unscientific.

§ 5.—REGISTRATION AND LABELLING

A mere Outline of a Field Naturalist's Duties would be inexcusably incomplete without mention of these important matters; and, because so much of the business of collecting must be left to be acquired in the school of experience, I am the more anxious to give explicit directions whenever, as in this instance, it is possible to do so.

Record your Observations Daily.—In one sense the specimens themselves are your record,—*prima facie* evidence of your industry and ability; and if labelled as I shall presently advise, they tell no small part of the whole story. But this is not enough; indeed, I am not sure that an ably conducted ornithological journal is not the better half of your operations. Under your editorship of labelling, specimens tell what they know about themselves; but you can tell much more yourself. Let us look at a day's work: You have shot and skinned so many birds, and laid them away labelled. You have made observations about them before shooting, and have observed a number of birds that you did not shoot. You have items of haunts and habits, abundance or scarcity; of manners and actions under special circumstances, as of pairing, nesting, laying, rearing young, feeding, migrating, and what not; various notes of birds are still ringing in your ears; and finally, you may have noted the absence of species you saw a while before, or had expected to occur in your vicinity. Meteorological and topographical items, especially when travelling, are often of great assistance in explaining the occurrences and actions of birds. Now *you* know these things, but very likely no one else does; and you know them *at the time*, but you will not recollect a tithe of them in a few weeks or months, to say nothing of years. Don't trust your memory; it will trip you up; what is clear now will grow obscure; what is found will be lost. Write down everything while it is fresh in your mind; write it out in full; time so spent will be time saved in the end, when you offer your researches to the discriminating public. Don't be satisfied with a dry-as-dust item; clothe a skeleton fact, and breathe life into it with thoughts that glow; let the paper smell of the woods. There's a pulse in a new fact; catch the rhythm before it dies. Keep off the quicksands of mere memorandum—that means something "to be remembered," which is just what you cannot do. Shun abbreviations; such keys rust with disuse, and may fail in after times to unlock the secret that should have been laid bare in the beginning. Use no signs intelligible only to yourself; your note-books may come to be overhauled by others whom you would not wish to disappoint. Be sparing of

sentiment, a delicate thing, easily degraded to drivel; crude enthusiasm always hacks instead of hewing. Beware of literary infelicities; "the written word remains," it may be, after you have passed away; put down nothing for your friend's blush, or your enemy's sneer; write as if a stranger were looking over your shoulder.

Ornithological Book-keeping may be left to your discretion and good taste in the details of execution. Each may consult his preferences for rulings, headings, and blank forms of all sorts, as well as particular modes of entry. But my experience has been that the entries it is advisable to make are too multifarious to be accommodated by the most ingenious formal ruling; unless, indeed, you make the conventional heading "Remarks" disproportionately wide, and commit to it everything not otherwise provided for. My preference is decidedly for a plain page. I use a strongly bound blank book, cap size, containing at least six or eight quires of good smooth paper; but smaller may be needed for travelling, even down to a pocket note-book. I would not advise a multiplicity of books, splitting up your record into different departments: let it be journal and register of specimens combined. (The registry of *your own collecting* has nothing to do with the register of your *cabinet of birds*, which is sure to include a proportion of specimens from other sources, received in exchange, donated, or purchased. I speak of this beyond.) I have found it convenient to commence a day's record with a register of the specimens secured, each entry consisting of a duplicate of the bird's label (see beyond), accompanied by any further remarks I have to make respecting the particular specimens; then to go on with the full of my day's observations, as suggested in the last paragraph. You thus have a register of collections in chronological order, told off with an unbroken series of numbers, checked with the routine label-items, and continually interspersed with the balance of your ornithological studies. Since your private field-number is sometimes an indispensable clew to the authentication of a specimen after it has left your own hands, never duplicate it. If you are collecting other objects of natural history besides birds, still have but one series of numbers; duly enter your mammal, or mineral, or whatever it is, in its place, with the number under which it happens to fall. Be scrupulously accurate with these and all other figures, as of dates and measurements. Always use black ink; lead-pencilling is never safe.

Labelling.—This should never be neglected. It is enough to make a sensitive ornithologist shiver to see a specimen without that indispensable appendage—a label. I am sorry to observe that the routine labelling of most collections is far from being satisfactory. A well-appointed label is something more than a slip of paper with the bird's name on it, and is still defective if, as is too often the

case, only the locality and collector are added. A complete label records the following particulars: 1. *Title* of the survey, voyage, exploration, or other expedition (if any), during which the specimen was collected. 2. *Name* of the person in charge of the same (and it may be remarked that the less he really cares about birds, and the less he actually interests himself to procure them, the more particular he will be about this). 3. *Title* of the institution or association (if any) under the auspices or patronage of which the specimen was procured, or for which it is designed. 4. *Name of collector;* partly to give credit where it is due, but principally to fix responsibility, and authenticate the rest of the items. 5. *Collector's number*, referring to his note-book, as just explained; if the specimen afterwards forms part of a general collection it usually acquires another number by new registry; the collector's then becoming the "original," as distinguished from the "current," number. 6. *Locality*, perhaps the most important of all the items. A specimen of unknown or even uncertain origin is worthless or nearly so. Lamentable confusion has only too often arisen in ornithological writings from vague or erroneous indications of locality. I should say that a specimen not authentic in this particular had better have its *supposed* origin erased. Nor will it do to say simply, for instance, "North America" or "England." The general geographical distribution of birds being according to recognised faunal areas, ornithologists generally know already the quarter of the globe from which any bird comes; the locality of particular specimens, therefore, should be fixed down to the very spot. If this be obscure, add the name of the nearest place to be found on a fairly good map, giving distance and direction. 7. *Date of collection*,—day of the month, and year. Among other reasons for this may be mentioned the fact that it is often important to know what season a particular plumage indicates. 8. *Sex*, and if possible also *age*, of the specimen,—an item that bespeaks its own importance. Ornithologists of all countries are agreed upon certain signs to indicate the sex. These are: ♂ for *male*, ♀ for *female*,—the symbols respectively of Mars and Venus. Immaturity is often denoted by the sign $_{\circ}$; thus, ♂ $_{\circ}$, young male. Or, we may write ♀ *ad.*, ♀ *yg.*, for adult female, young female, respectively. It is preferable, however, to use the language of science, not our vernacular, and say ♂ *juv.* (*juvenis*, young). *Nupt.* signifies breeding plumage; *hornot.* means a bird of the year. 9. *Measurements* of length, and of extent of wings; the former can only be obtained approximately, and the latter not at all, from a prepared specimen. 10. *Colour* of the eyes, and of the bill, feet, or other naked or soft parts, the tints of which may change in drying. 11. *Miscellaneous particulars*, such as contents of stomach, special

circumstances of capture, vernacular name, etc. 12. *Scientific name of the bird.* This is really the least important item of all, though generally thought to take precedence. But a bird labels itself, so to speak; and nature's label may be deciphered at any time. In fact, I would enjoin upon the collector not to write out the supposed name of the bird in the field, unless the species is so well known as to be absolutely unquestionable. Proper identification, in any case to which the slightest doubt may attach, can only be made after critical study in the closet with ample facilities for examination and comparison. But it is always well to note on the label the local vernacular name; for native names, especially un-English ones, may become valuable items of information. The first eight items above, and the twelfth, usually constitute the face or obverse of a label; the rest are commonly written on the back or reverse side. Labels should be of light cardboard, or very stiff writing paper; they may be dressed attractively, as fancy suggests; the general items of a large number of specimens are best printed; the special ones must of course be written. Shape is immaterial. A slip about three inches long and two-thirds of an inch wide will do very well for anything, from a hawk to a humming-bird. Something like the shipping-tag used by merchants is excellent, particularly for larger objects. It seems most natural to attach the string to the left-hand end. The slip should be tied so as to swing just clear of the bird's legs, but not loose enough to dangle several inches, for in that case the labels are continually tangling with each other when the birds are laid away in drawers. The following forms show the face and back of the last label I happened to write before these lines were originally penned; they represent the size and shape that I find most convenient for general purposes; while the legend illustrates every one of the twelve items above specified.

Explorations in Dakota. Dr. Elliott Coues, U.S.A. Institution

No. 2655. Buteo borealis (Gm.) V. ♀ juv.

Fort Randall, Missouri River. Oct. 29, 1872.

23.00 × 53.00 × 17.50. — Eyes yellowish-gray; bill horn-blue, darker at tip; cere wax-yellow; tarsi dull yellowish; claws bluish-black. Stomach contained portions of a rabbit; also, a large tapeworm.

Reverse.

Directions for Measurement may be inserted here, as this matter pertains rightfully to the recording of specimens. The following instructions apply not only to length and extent, but to the principal other dimensions, which may be taken at any time. For large birds, a tape-line showing inches and fourths will do; for smaller ones, a foot-rule graduated for inches and eighths, or better, decimals to hundredths, must be used; and for all nice measurements the dividers are indispensable. *Length:* Distance between the tip of the bill and end of the longest tail-feather. Lay the bird on its back on the ruler on a table; take hold of the bill with one hand and of both legs with the other; pull with reasonable force to get the curve all out of the neck; hold the bird thus with the tip of the bill flush with one end of the ruler, and see where the end of the tail points. Put the tape-line in place of the ruler, in the same way, for larger birds. *Extent:* Distance between the tips of the outspread wings. They must be fully outstretched, with the bird on its back, crosswise on the ruler, its bill pointing to your breast. Take hold of right and left metacarpus with the thumb and forefinger of your left and right hand respectively, stretch with reasonable force, getting one wing-tip flush with one end of the ruler, and see how far the other wing-tip reaches. With large birds pull as hard as you please, and use the table, floor, or side of the room; mark the points and apply tape-line. *Length of wing:* Distance from the carpal angle formed at the bend of the wing to the end of the longest primary. Take it with compasses for small birds. In birds with a convex wing, do not lay the tape-line over the curve, but under the wing in a straight line. This measurement is the one called, for short, "the wing." *Length of tail:* Distance from the roots of the rectrices to the end of the longest one. Feel for the pope's-nose; in either a fresh or dried specimen there is more or less of a palpable lump into which the tail-feathers stick. Guess as near as you can to the middle of this lump; place the end of the ruler opposite this point, and see where the tip of the longest tail-feather comes. *Length of bill:* Some take the curve of the upper mandible; others the side of the upper mandible from the feathers; others the gape, etc. I take the *chord of the culmen.* Place one foot of the dividers on the culmen just where the feathers end; no matter whether the culmen runs up on the forehead, or the frontal feathers run out on the culmen, and no matter whether the culmen is straight or curved. Then with me the *length of the bill* is the shortest distance from the point just indicated to the tip of the upper mandible: measure it with the dividers. In a straight bill of course it is the length of the culmen itself; in a curved bill, however, it is quite another thing. *Length of tarsus:* Distance between the joint of the tarsus with the leg above, and

that with the first phalanx of the middle toe below. Measure it always with dividers, and in front of the leg. *Length of toes:* Distance in a straight line along the upper surface of a toe from the point last indicated to the root of the claw on top. Length of toe is to be taken without the claw, unless otherwise specified. *Length of the claws:* Distance in a *straight line* from the point last indicated to the tip of the claw. *Length of head* is often a convenient dimension for comparison with the bill. Set one foot of the dividers over the base of the culmen (determined as above) and allow the other to slip snugly down over the arch of the occiput.

§ 6.—INSTRUMENTS, MATERIALS, AND FIXTURES FOR PREPARING BIRDSKINS

Instruments.—The only indispensable instrument is a pair of scissors or a knife; practically, you want both of these, a pair of spring-forceps, and a knitting-needle, or some similar wooden or ivory object. I have made hundreds of birdskins consecutively without touching another tool. *Persicos odi, puer, apparatus!* I always mistrust the emphasis of a collector who makes a flourish of instruments. You might be surprised to see what a meagre, shabby-looking kit our best taxidermists work with. Stick to your scissors, knife, forceps, and needle. But you may as well buy, at the outset, a common dissecting-case, such as medical students begin business with; it is very cheap, and if there are some unnecessary things in it, it makes a nice little box in which to keep your tools. The case contains, among other things, several scalpels, just the knives you want; a "cartilage-knife," which is nothing but a stout scalpel, suitable for large birds; the best kind of scissors for your purpose, with short blades and long handles—if kneed at the hinge so much the better; spring forceps, the very thing; a blow-pipe, useful in many ways and answering instead of a knitting-needle; and some little steel hooks, chained together, which you may want to use. But you will also require, for large birds, a very heavy pair of scissors, or small shears, short-bladed and long-handled, and a stout pair of bone nippers. Have some pins and needles; surgical needles, which cut instead of punching, are the best. Get a hone or strop, if you wish, and a feather-duster. Use of scissors requires no comment, and I would urge their habitual employ instead of the knife-blade; I do nine-tenths of my cutting with scissors, and find it much the easiest. A double-lever is twice as effective as a single one. Moreover, scalpels need constant sharpening; mine are generally too dull

to cut much with, and I suppose I am like other people—while scissors stay sharp enough. The flat, thin ivory or ebony handle of the scalpel is about as useful as the blade. Finger-nails, which were made before scalpels, are a mighty help. Forceps are almost indispensable for seizing and holding parts too small or too remote to be grasped by the fingers. The knitting-needle is wanted for a specific purpose noted beyond. The shears or nippers are only needed for what the ordinary scissors are too weak to do.

Materials.—(*a*) *For stuffing.* "What do you stuff 'em with?" is usually the first question of idle curiosity about taxidermy, as if that were the great point; whereas the stuffing is so small a matter that one might reply, "Anything, except brickbats!" But if stuffing birds were the final cause of *cotton*, that admirable substance could not be more perfectly adapted than it is to the purpose. Ordinary raw cotton-batting or wadding is what you want. When I can get it I never think of using anything else for small birds. I would use it for all birds were expense no object. Here *tow* comes in; there is a fine, clean, bleached article of tow prepared for surgical dressings; this is the best, but any will do. Some say chop your tow fine; this is harmless, but unnecessary. A crumpled newspaper, wrapped with tow, is first-rate for a large bird. Failing cotton or tow, any *soft, light, dry, vegetable substance* may be made to answer,—rags, paper, crumbled leaves, fine dried grass, soft fibrous inner bark, etc.; the down of certain plants, as thistle and silkweed, makes an exquisite filling for small birds. But I will qualify my remark about brickbats by saying: *Never put hair, wool, feathers, or any other* ANIMAL *substance in a birdskin;* far better leave it empty: for, as we shall see in the sequel, bugs come fast enough, without being invited into a snug nest. (*b*) *For preserving.* ARSENIC,—not the pure metal properly so called, but arsenic of the shops, or arsenious acid,—is the great preservative. Use dry powdered arsenic, plenty of it, and nothing else. There is no substitute for arsenic worthy of the name, and no preparation of arsenic so good as the simple substance. Various kinds of "arsenical soap" were and may still be in vogue; it is a nasty, greasy substance; and although efficacious enough, there is a very serious hygienic objection to its use.[1] Arsenic, I need not say, is a violent irritant poison, and must therefore be duly guarded, but may be used with perfect impunity. It is a very heavy substance, not appreciably volatile at ordinary temperatures, and therefore not

[1] "Strange as it may appear to some, I would say avoid especially all the so-called arsenical soaps; they are at best but filthy preparations; besides, it is a fact to which I can bear painful testimony that they are, especially when applied to a greasy skin, poisonous in the extreme. I have been so badly poisoned, while working upon the skins of some fat water birds that had been prepared with arsenical soap, as to be made seriously ill, the poison having worked into the system through some small wounds or scratches on my hand. Had pure arsenic been used in preparing the skins,

liable, as some suppose, to be breathed, to any perceptible, much less injurious, extent. It will not at once enter the pores of healthy unbroken skin; so it is no matter if it gets on the fingers. The exceedingly minute quantity that may be supposed to find its way into the system in the course of time is believed by many competent physicians to be rather beneficial as a tonic. I will not commit myself to this; for, though I have never felt better than when working daily with arsenic, I do not know how much my health was improved by the outdoor exercise always taken at the same time. The simple precautions are, not to let it lie too long in contact with the skin, nor get into an abrasion, nor under the nails. It will convert a scratch or cut into a festering sore of some little severity; while if lodged under the nails it soon shows itself by soreness, increased by pressure; a white speck appears, then a tiny abscess forms, discharges, and gets well in a few days. Your precautions really respect other persons more than yourself; the receptacle should be conspicuously labelled "POISON!" Arsenic is a good friend; besides preserving our birds, it keeps busybodies and meddlesome folks away from the scene of operations, by raising a wholesome suspicion of the taxidermist's surroundings. It may be kept in the tin pots in which it is usually sold; but some shallower, broader receptacle is more convenient. A little drawer say 6 × 6 inches, and an inch deep, to slip under the edge of the table, or a similar compartment in a large drawer, will be found handy. A salt-spoon, or little wooden shovel whittled like one, is nice to use it with, though it is in fact generally taken up with the handle of the scalpel. As stated, there is no substitute for arsenic; but at a pinch you can make temporary shift with the following, among other articles: table salt, or saltpetre, or charcoal strewn plentifully; strong solution of corrosive sublimate, brushed over the skin inside; creosote; impure carbolic acid—these last two are quite efficacious, but they smell horribly for an indefinite period. A bird threatening to decompose before you are ready to skin it, may be saved for a while by injecting weak carbolic acid or creosote down the throat and up the fundament; or by disembowelling, and filling the cavity with powdered charcoal. (*c*) *For cleansing*. *Gypsum* is an almost indispensable material for cleansing soiled plumage. Gypsum is properly native hydrated sulphate of lime; the article referred to is "plaster of Paris" or gypsum heated up to 260° F. (by which the water of crystallisation is driven off) and then finely pulverised.

the effect would not have been *as bad*, although grease and arsenic are generally a blood-poison in *some* degree; but when combined with 'soap' the effect, at least as far as my experience goes, is much more injurious" (MAYNARD, *Guide*, p. 12). In indorsing this, I would add that the combination is the more poisonous, in all probability, simply because the soap, being detersive, mechanically facilitates the entrance of the poison, without, however, chemically increasing its virulence.

When mixed with water it soon solidifies, the original hydrate being again formed. The mode of using it is indicated beyond. It is most conveniently kept in a shallow tray, say a foot square, and an inch or two deep, which had better, furthermore, slide under the table as a drawer; or form a compartment of a larger drawer. *Keep gypsum and arsenic in different-looking receptacles,* not so much to keep from poisoning yourself, as to keep from *not* poisoning a birdskin. They look much alike, and skinning becomes such a mechanical process that you may get hold of the wrong article when your thoughts are wandering in the woods. Gypsum, like arsenic, has no worthy rival in its own field; some substitutes, in the order of their applicability, are: corn-meal, probably the best thing after gypsum; calcined magnesia (very good but too light—it floats in the air, and makes you cough); bicarbonate of magnesia; powdered chalk ("prepared chalk," *creta præparata* of the drug shops, is the best kind); fine wood-ashes; clean dry loam. No article, however powdery when dry, that contains a glutinous principle, as for instance gum-arabic or flour, is admissible. (*d*) *For wrapping,* you want a thin, pliable, strong paper; toilet-paper is the very best; newspaper is pretty good. For making the cones or cylinders in which birdskins may be set to dry, a stiffer article is required; writing paper answers perfectly.

Naturalists habitually carry a Pocket Lens, much as other people do a watch. You will find a magnifying glass very convenient in your search for the sexual organs of small birds when obscure, as they frequently are, out of the breeding-season; in picking lice from plumage, to send to your entomological friend, who will very likely pronounce them to be of a new species; and for other purposes.

Fixtures.—When travelling, your fixtures must ordinarily be limited to a collecting-chest; you will have to skin birds on the top of this, on the tail-board of a wagon, or on your lap, as the case may be. The chest should be very substantial—iron-bound is best; strong as to hinges and lock—and have handles. A good size is 30 × 18 × 18 inches. Let it be fitted with a set of trays; the bottom one say four inches deep; the rest shallower; the top one very shallow, and divided into compartments for your tools and materials, unless you fix these on the under side of the lid. Start out with all the trays full of cotton or tow. At home have a room to yourself, if possible; taxidermy makes a mess to which your wife may object, and arsenic must not come in the way of children. At any rate have your own table. Great cleanliness is indispensable, especially when doing much work in hot weather, for the place soon smells sour if neglected. I use no special receptacle for offal, for this only makes another article to be cleaned; lay down a piece of

paper for the refuse, and throw the whole away. A perfectly smooth surface is desirable. I generally have a large pane of window-glass on the table before me. It will really be found advantageous to have a scale of inches scratched on the edge of the table; only a small part of it need be fractionally subdivided; this replaces the foot-rule and tape-line, just as the tacks of a dry-goods counter answer for the yard-stick. You will find it worth while to rig some sort of a derrick arrangement, which you can readily devise, on one end of the table, to hitch your hook to, if you hang your birds up to skin them; they should swing clear of everything. The table should have a large general drawer, with a little drawer for gypsum and arsenic, unless these be kept elsewhere. Stuffing may be kept in a box under the table, and make a nice footstool; or in a bag slung to the table leg.

§ 7.—HOW TO MAKE A BIRDSKIN

(a) The Regular Process

Lay the Bird on its Back, the bill pointing to your right[1] elbow. Take the scalpel like a pen, with edge of blade uppermost, and run a straight furrow through the feathers along the middle line of the belly, from end of the breast-bone to the vent. Part the feathers completely, and keep them parted.[2] Observe a strip of skin either perfectly naked, or only covered with short down; this is the line for incision. Take scissors, stick in the pointed blade just over the end of the breast-bone, cut in a straight line thence to and into the vent; cut extremely shallow.[3]

Take the forceps in your left hand, and scalpel in your right, both held pen-wise, and with the forceps seize and lift up one of the edges of the cut skin, gently pressing away the belly-walls with

[1] Reverse this and following directions for position, if you are left-handed.

[2] The motion is exactly like stroking the right and left sides of a moustache apart; you would never dress the hairs smoothly away from the middle line, by poking from ends to root; nor will the feathers stay aside, unless stroked away from base to tip.

[3] The skin over the belly is thin as tissue paper in a small bird; the chances are you will at first cut the walls of the belly too, opening the cavity; this is no great matter, for a pledget of cotton will keep the bowels in; nevertheless, try to divide skin only. Reason for cutting into vent: this orifice makes a nice natural termination of the incision, buttonhole-wise, and may keep the end of the cut from tearing around the root of the tail. Reason for beginning to cut over the edge of the breast-bone: the muscular walls of the belly are very thin, and stick so close to the skin that you may be in danger of attempting to remove them with the skin, instead of removing the skin from them; whereas you cannot remove anything but skin from over the breast-bone, so you have a guide at the start. You can tell skin from belly-wall, by its livid, translucent whitishness instead of redness.

the scalpel-point; no cutting is required; the skin may be peeled off without trouble. Skin away till you meet an obstacle; it is the thigh. Lay down the instruments; with your left hand take hold of the leg outside at the shank; put your right forefinger under the raised flap of skin, and feel a bump; it is the knee; push up the leg till this bump comes into view; hold it so. Take the scissors in your right hand; tuck one blade under the concavity of the knee, and sever the joint at a stroke; then the thigh is left with the rest of the body, while the rest of the leg is dissevered and hangs only by skin. Push the leg farther up till it has slipped out of its sheath of skin, like a finger out of a glove, down to the heel-joint. You have now to clear off the flesh and leave the bone there; you may scrape till this is done, but there is a better way. Stick the closed points of the scissors in among the muscles just below the head of the bone, then separate the blades just wide enough to grasp the bone; snip off its head; draw the head to one side; all the muscles follow, being there attached; strip them downward from the bone; the bone is left naked, with the muscle hanging by a bundle of tendons ("leaders") at its foot; sever these tendons collectively at a stroke. This whole performance will occupy about three seconds, after practice; and you may soon discover you can nick off the head of the bone of a small bird with the thumb-nail. Draw the leg-bone back into its sheath, and leave it. Repeat the foregoing steps on the other side of the bird. If you are bothered by the skin-flaps settling against the belly-walls, insert a fluff of cotton. Keep the feathers out of the wound; cotton and the moustache movement will do it. Next you must sever the tail from the body, leaving a small "pope's-nose" for the feathers to stay stuck into. Put the bird in the hollow of your lightly closed left hand, tail upward, belly toward you; or, if too large for this, stand it on its breast on the table in similar position. Throw your left forefinger across the front (under side) of the tail, pressing a little backward; take the scissors, cut the end of the lower bowel free first, then peck away at bone and muscle with cautious snips, till the tail-stump is dissevered from the rump, and the tail hangs only by skin. You will soon learn to do it all at one stroke; but you cannot be too careful at first; you are cutting right down on to the skin over the top of the pope's-nose, and if you divide this, the bird will part company with its tail altogether. Now you have the rump-stump protruding naked; the legs dangling on either side; the tail hanging loose down over the bird's back. Lay down scissors, take up forceps[1] in your left hand; with them seize and

[1] Or at this stage you may instead stick a hook into a firm part of the rump, and hang up the bird about the level of your breast; you thus have both hands free to work with. This is advisable with all birds too large to be readily taken in

hold the stump of the rump; and with point or handle of scalpel in the other hand, with finger-tips, or with thumb-nail (best), gently press down on and peel away skin.[1] No cutting will be required (usually) till you come to the wings: the skin peels off (usually) as easily as an orange-rind; as fast as it is loosened, evert it; that is, make it continually turn itself more and more completely inside out. Work thus till you are stopped by the obtruding wings.[2] You have to sever the wing from the body at the shoulder, just as you did the leg at the knee, and leave it hanging by skin alone. Take your scissors,[3] as soon as the upper arm is exposed, and cut through flesh and bone alike at one stroke, a little below (outside of) the shoulder-joint. Do the same with the other wing. As soon as the wings are severed the body has been skinned to the root of the neck; the process becomes very easy; the neck almost slips out of its sheath of itself; and if you have properly attended to keeping the feathers out of the wound and to continual eversion of the skin, you now find you have a naked body connected dumb-bell-wise by a naked neck to a cap of reversed skin into which the head has disappeared, from the inside of which the legs and wings dangle, and around the edges of which is a row of plumage *and a tail.*[4] *Here comes up an important consideration*: the skin, plumage, legs, wings, and tail together weigh something,—enough to stretch[5] unduly the skin of the neck, from the small cylinder of

hand, and will help you, at first, with any bird. But there is really no use of it with a small bird, and you may as well learn the best way of working at first as afterward.

[1] The idea of the whole movement is exactly like ungloving your hand from the wrist, by turning the glove inside out to the very finger tips. Some say, *pull* off the skin; I say *never pull* a bird's skin under any circumstances: *push it off*, always operating at lines of contact of skin with body, never upon areas of skin already detached.

[2] The elbows will get in your way before you reach the point of attack, namely, the shoulder, unless the wings were completely relaxed (as was essential, indeed, if you measured alar expanse correctly). Think what a difference it would make, were you skinning a man through a slit in the belly, whether his arms were stretched above his head or pinned against his ribs. It is just the same with a bird. When properly relaxed the wings are readily pressed away toward the bird's head, so that the shoulders are encountered before the elbows.

[3] Shears will be required to crash through a large arm-bone. Or, you may with the scalpel unjoint the shoulder. The joint will be found higher up and deeper among the breast muscles than you might suppose, unless you are used to carving fowls at table. With a small bird, you may snap the bone with the thumb-nail and tear asunder the muscles in an instant.

[4] You find that the little straight cut you made along the belly has somehow become a hole larger than the greatest girth of the bird; be undismayed; it is all right.

[5] If you have up to this point properly *pushed* off the skin instead of *pulling* it, there is as yet probably no stretching of any consequence; but, in skinning the head, which comes next, it is almost impossible for a beginner to avoid stretching to an extent involving great damage to the good looks of a skin. Try your utmost, by delicacy of manipulation at the lines of contact of skin with flesh, and only there, to

which they are now suspended; the whole mass must be supported. For small birds, gather it in the hollow of your left hand, letting the body swing over the back of your hand out of the way; for large ones, rest the affair on the table or your lap. To skin the head, secure the body in the position just indicated, by confining the neck between your left thumb and forefinger; bring the right fingers and thumb to a cone over the head, and draw it out with gentle force; or, holding the head itself between the left thumb and forefinger, insert the handle of the scalpel between the skin and skull, and pry a little, to enlarge the neck-cylinder of skin enough to let the head pass. It will generally[1] slip out of its hood very readily, as far as its greatest diameter;[2] there it sticks, being in fact pinned by the ears. Still holding the bird as before, with the point of the scalpel handled like a nut-picker, or with your thumb-nail, detach the delicate membrane that lines the ear-opening; do the same for the other ear. The skull is then shelled out to the eyes, and will skin no farther of its own accord, being again attached by a membrane, around the border of the eye-socket. Holding the scalpel as before, run its edge around an arc (a semi-circle is enough to let you into the orbit) of the circumference, dissevering the membrane from the bone. Reverse the scalpel, and scoop out the eyeball with the end of the handle; you bring out the eye betwixt the ball of your thumb and the handle of the instrument, tearing apart the optic nerve and the conjunctival tissue, but taking care not to open the eyeball[3] or lacerate the eyelids. Do the same with the other eye. The head is then skinned far enough; there is no use of getting quite to the base of the bill. You have now to get rid of the brain and flesh of the nape and jaws,[4] and leave most of the skull in; the cranial dome makes the only perfect "stuffing" for the skin of the head. This is all done at once by only four particular cuts. Hold the head

prevent lengthwise stretching. Crosswise distension is of no consequence; in fact more or less of it is usually required to skin the head, and it tends to counteract the ill effect of undue elongation.

[1] The special case of head too large for the calibre of the neck is treated beyond.

[2] And you will at once find a great apparent increase of amount of free skin in your hand, owing to release and extension of all that was before shortened in length by circular distension, in enlargement of the neck-cylinder.

[3] An eyeball is much larger than it looks from the outside; if you stick the instrument straight into the socket, you may punch a hole in the ball and let out the water—a very disagreeable complication. Insinuate the knife-handle close to the rim of the socket, and hug the wall of the cavity throughout.

[4] You may of course at this stage cut off the neck at the nape, punch a hole in the base of the skull, dig out the brains, and scrape away at the jaw-muscles till you are satisfied or tired; an unnecessary job, during which the skin may have become dry and shrivelled and hard to turn right side out. The operation described in the text may require five seconds, perhaps.

between your left thumb and fingers, the bill pointing towards you, the bird's palate facing you; you observe a space bounded behind by the base of the skull where the neck joins, in front by the floor of the mouth, on either side by the prongs of the under jaw,—these last especially prominent. Take the scissors; stick one blade just inside one branch of the lower jaw, thence into the eye-socket which lies below (the head being upside down), thence into the brain-box; make a cut parallel with the jaw, just inside of it, bringing the upper scissor-blade perpendicularly downward, crashing through the skull just inside of the angle of the jaw. Duplicate this cut on the other side. Connect the anterior ends of these cuts by a transverse one across the floor and roof of the mouth. Connect the posterior ends of the side cuts by one across the back of the skull near its base,—just where the nape-muscle ceases to override the cranium. You have enclosed and cut out a squarish-shaped mass of bone and muscle, and, on gently pulling the neck (to which of course it remains attached) the whole affair comes out, bringing the brain with it, but leaving the entire roof of the skull supported on a scaffolding of jaw-bone. It only remains to skin the wings. Seize the arm-stump with fingers or forceps; the upper arm is readily drawn from its sheath as far as the elbow; but the wing must be skinned to the wrist (carpus—"bend of the wing"); yet it will not come out easily, because the secondary quills grow to one of the forearm bones (the ulna), pinning down the skin the whole way along a series of points. To break up these connections, hold the upper arm firmly with the left thumb and forefinger, the convexity of the elbow looking towards you; *press the right thumb-nail closely against the back edge of the ulna, and strip downward, scraping the bone with the nail the whole way. If you only hit the line of* adhesions, there is no trouble at all about this. Now you want to leave in one of the two forearm bones, to preserve sufficiently the shape of the limb, but to remove the other, with the upper-arm bone and all the flesh. It is done in a moment: stick the point of the scissors between the heads of the two forearm bones, and cut the hinder one (ulna) away from the elbow; then the other forearm bone (radius), bearing on its near end the elbow and the whole upper-arm, is to be stripped away from the ulna, taking with it the flesh of the forearm, and to be cut off at its far end close to the wrist-joint, one stroke severing the bone and all the tendons that pass over the wrist to the hand; then the ulna, bare of flesh, is alone left in, attached at the wrist. Draw gently on the wing from the outside till it slips into the natural position whence you everted it. Do the same for the other wing. This finishes the skinning process. The skin is now to be turned right side out. Begin any way you please, till you see the point of the bill reappearing among

the feathers; seize it with fingers or forceps, as convenient, and use it for gentle traction. But by no means pull it out by holding on to the rear end of the skin—that would infallibly stretch the skin. Holding the bill, make a cylinder of your left hand and coax the skin backward with a sort of milking motion. It will come easily enough, until the final stage of getting the head back into its skull-cap; this may require some little dexterity; but you cannot fail to get the head in, if you remember what you did to get it out. When this is fairly accomplished, you for the first time have the pleasure of seeing something that looks like a birdskin. Your next care is to apply arsenic. Lay the skin on its back, the opening toward you and wide spread, so the interior is in view. Run the scalpel-handle into the neck to dilate that cylinder until you can see the skull; find your way to the orifices of the legs and wings; expose the pope's-nose; thus you have not only the general skin surface, but all the points where some traces of flesh were left, fairly in view. Put in arsenic; send some down the neck, making sure it reaches and plentifully besprinkles the whole skull; drop a little in each wing-hole and leg-hole; leave a small pile at the root of the tail; strew some more over the skin at large. The simple rule is, put in as much arsenic as will stick anywhere. Then close the opening, and shake up the skin; move the head about by the bill; rustle the wings and move the legs; this distributes the poison thoroughly. If you have got in more than is necessary, as you may judge by seeing it piled up dry, anywhere, hold the skin with the opening downward over the poison-drawer, and give it a flip and let the superfluous powder fall out. Now for the "make-up," upon which the beauty of the preparation depends. First get the empty skin into good shape. Let it lie on its back; draw it straight out to its natural length. See that the skin of the head fits snugly; that the eyes, ears, and jaws are in place. Expand the wings to make sure that the bone is in place, and fold them so that the quills override each other naturally; set the tail-feathers shingle-wise also; draw down the legs and leave them straddling wide apart. Give the plumage a preliminary dressing; if the skin is free from kinks and creases, the feathers come naturally into place; particular ones that may be awry should be set right, as may be generally done by stroking, or by lifting them free repeatedly, and letting them fall; if any (through carelessness) remain turned into the opening, they should be carefully picked out. Remove all traces of gypsum or arsenic with the feather-duster. The stuffing is to be put in through the opening in the belly; the art is to get in just enough, in the right places. It would never do to push in pellets of cotton, as you would stuff a pillow-case, till the skin is filled up; no subsequent skill in setting could remove the distortion that

would result.[1] It takes just *four* pieces of stuffing—one for each eye, one for the neck, and one for the body; while it requires rather less than half as much stuffing as an inexperienced person might suppose. Take a shred of cotton that will make a tight ball as large as the bird's eye; stick it on the end of your knitting-needle, and by twirling the needle whilst the cotton is confined in your finger tips, you make a neat ball. Introduce this through the belly-opening into the eye-socket; if you have cut away skull enough, as already directed, it will go right in; disengage the needle with a reverse twirl, and withdraw it. Take hold of the bill with one hand, and with the forceps in the other, dress the eyelids neatly and naturally over the elastic substance within. Repeat for the other eye. Take next a shred of cotton that will roll into a firm cylinder rather less than the size of the bird's neck. Roll it on the needle much as you did the eyeball, introduce it in the same way, and ram it firmly into the base of the skull; disengage the needle by twirling it the other way, and withdraw it, taking care not to dislodge the cotton neck. If now you peep into the skin you will see the end of this artificial neck; push it up against the skin of the breast,—it must not lie down on the back between the shoulders.[2] The body-wad comes next, to imitate the size and shape of the bird's trunk. Take a mass of cotton you think will be enough, and take about *half* of this; that will be plenty (cotton is very elastic). It should make a tolerably firm ball, rather egg-shaped, swelling at the breast, smaller behind. If you simply squeeze up the cotton, it will not stay compressed; it requires a motion something like that which bakers employ to knead dough into the shape of a loaf. Keep tucking over the borders of the cotton till the desired shape and firmness are attained. Insert the

[1] For any ordinary bird up to the size of a crow, it is often directed that the leg-bones and wing-bones be wrapped with cotton or tow. I should not think of putting anything around the wing-bones of any bird up to the size of an eagle, swan, or pelican. Examination of a skinned wing will show how extremely compact it is, except just at the shoulder. What you remove will never make any difference from the outside, while you would almost inevitably get in too much, not of the right shape, and make an awkward bulging no art would remedy; I say, then, leave the wings of all but the largest birds *empty*, and put in very little cotton under any circumstances. As for legs, the whole host of small perching birds need no wrapping whatever; depend upon it you will make a nicer skin without wrapping. But large birds and those with very muscular or otherwise prominent legs must have the removal of flesh compensated. I treat of these cases beyond.

[2] Although a bird's neck is really, of course, in direct continuation of the backbone, yet the natural sigmoid curve of the neck is such that it virtually takes departure rather from the breast, its lower curve being received between the prongs of the merrythought. This is what we must imitate instead of the true anatomy. If you let the end of the neck lie between the shoulders, it will infallibly press them apart, so that the interscapular plumage cannot shingle over the scapular feathers as it should, and a gaping place, showing down or even naked skin, will result. Likewise, if the neck be made too large (the chances are that way at first), the same result follows. These seemingly trifling points are very important.

ball between the blades of the forceps in such way that the instrument confines the folded-over edges, and with a wriggling motion insinuate it aright into the body. Before relaxing the forceps, put your thumb and forefinger in the bird's armpits, and pinch the shoulders together till they almost touch; this is to make sure that there is no stuffing between the shoulders,—the whole mass lying breastwards. Loosen the forceps and withdraw them. If the ball is rightly made and tucked in, the elasticity of the cotton will chiefly expend itself in puffing out the breast, which is just what is wanted. Be careful not to push the body too far in; if it impacts against the skin of the neck, this will infallibly stretch, driving the shoulders apart, and no art will remedy the unsightly gap resulting. You see I dwell on this matter of the shoulders; the whole knack of stuffing correctly focuses just over the shoulders. If you find you have made the body too large, pull it out and make a smaller one; if it fits nicely about the shoulders, but is too long to go in, or too puffy over the belly, let it stay, and pick away shreds at the open end till the redundancy is remedied. Your bird is now stuffed. Close the opening by bringing the edges of the original cut together. There is no use of sewing up the cut for a small bird; if the stuffing is correct, the feathers will hide the opening; and if they do not, it is no matter. You are not making an object for a show-case, but for a naturalist's cabinet. Supposing you to have been so far successful, little remains to be done; the skin already looks very much like a dead bird; you have only to give the finishing touches, and "set" it. Fixing the wings nicely is a great point. Fold each wing closely; see that the carpal bend is well defined, that the coverts show their several oblique rows perfectly, that all the quills override each other like shingles. Tuck the folded wings close up to the body—rather on the bird's back than along its sides; see that the wing tips meet over the tail (under the tail as the bird lies on its back); let the carpal angle nestle in the plumage; have the shoulders close together, so that the interscapular feathers shingle over the scapulars. If the wing be pressed in *too* tightly, the scapulars will rise up on end; there must be neither furrow nor ridge about the insertion of the wings; everything must lie perfectly smooth. At this stage of the process lift up the skin gingerly, and let it slip head first through one hand after the other, pressing here or there to correct a deformity, or uniformly to make the whole skin compact. The wings set, next bring the legs together, so that the bones within the skin lie parallel with each other; bend the heel-joint a little, to let the tarsi cross each other about their middle; lay them sidewise on the tail, so that the naturally flexed toes lie flat, all the claws facing each other. See that the neck is perfectly straight, and, if anything, shortened rather than out-

stretched; have the crown of the head flat on the table, the bill pointing straight forward,[1] the mandibles shut tightly.[2] Never attempt any fancy attitudes with a birdskin; the simpler and more compactly it is made up the better.[3] Finally, I say, hang over your bird (if you have time); dress better the feathers that were well dressed before; perfect every curve; finish caressingly, and put it away tenderly, as you hope to be shriven yourself when the time comes.

There are several ways of laying a birdskin. A common, easy, and slovenly way is to thrust it head first into a paper cone; but it makes a hollow-chested, pot-bellied object, unpleasant to see, and renders your nice work on the make-up futile. A paper cylinder, corresponding in calibre to the greatest girth of the birdskin, binds the wings well, and makes a good specimen. Remarking that there are some detestable practices, such as hanging up a bird by a string through the nose (methods only to be mentioned to be condemned), I will tell you the easiest and best way by which the most elegant and tasteful results are secured. The skins are simply laid away in cotton, just as they come from your hands. Take a considerable wad of cotton, make a bed of it, lay the specimen in, and tuck it up nicely around the edges. I generally take a thin sheet of cotton wadding, the sizing of which confers some textile consistency, and wrap the bird completely but lightly in it. By loosening or tightening a trifle here or there, laying down a pillow or other special slight pressure, the most delicate contour-lines may be preserved with fidelity. Unnecessary pother is sometimes made about *drying* skins; the fact being that under ordinary circumstances they could not be kept from drying perfectly; and they dry in

[1] Exceptions. Woodpeckers, ducks, and some other birds treated of beyond, are best set with the head flat on one side, the bill pointing obliquely to the right or left; owls, with the bill pointing straight up in the air as the bird lies on its back.

[2] If the mandibles gape, run a thread through the nostrils and tie it tightly under the bill. Or, since this injures the nostrils (and we frequently want to examine their structure), stick a pin in under the bill close to the gonys, driving it obliquely into the palate. Sometimes the skin of the throat looks sunken betwixt the sides of the jaw. A shred of cotton introduced with forceps through the mouth will obviate this.

[3] Don't cock up the head, trying to impart a knowing air—it cannot be done, and only makes the poor bird look ridiculous. Don't lay the skin on one side, with the legs in perching position, and don't spread the wings—the bird will never perch nor fly again, and the suggestion is not in keeping. The only permissible departure from the rule of severe simplicity is when some special ornament, as a fine crest, may be naturally displayed, or some hidden markings be brought out, or a shape of tail or wing to be perpetuated; but in all such cases the "spread-eagle" style should be sparingly indulged. It is, however, frequently desirable to give some special set to hide a defect, as loss of plumage, etc.; this may often be accomplished very cunningly, with excellent result. No rules for this can be laid down, since the details vary in every case; but in general the weak spot may be hidden by contracting the skin of the place, and then setting the bird in an attitude that naturally corresponds, thus making a virtue of necessity.

exactly the shape they are set, if not accidentally pressed upon. At sea, however, or during unusually protracted wet weather, they of course dry slowly, and may require some attention to prevent mildew or souring, especially in the cases of very large, thick-skinned, or greasy specimens. Thorough poisoning, and drying by a fire, or placing in the sun, will always answer. Very close packing retards drying. When travelling, or operating under other circumstances requiring economy of space, you must not expect to turn out your collection in elegant order. Perfection of contour-lines can only be secured by putting each specimen away by itself; undue pressure is always liable to produce unhappily *outré* configuration of a skin. Trays in a packing box are of great service in limiting possibilities of pressure; they should be shallow; one four inches deep will take a well-stuffed hen-hawk, for example, or accommodate from three to six sparrows atop of one another. It is well to sort out your specimens somewhat according to size, to keep heavy ones off little ones; though the chinks around the former may usually be economised with advantage by packing in the less valuable or the less neatly prepared of the latter. When limited to a travelling chest, I generally pass in the skins as fast as made, packing them solid in one sense, yet finding a nice resting-place for each. If each rests in its own cotton coffin, it is astonishing how close they may be laid without harm, and how many will go in a given space; a tray 30 × 18 × 4 inches will easily hold three hundred and fifty birds six inches long. As a tray fills up, the drier ones first put in may be submitted to more pressure. A skin originally dried in good shape may subsequently be pressed perfectly flat without material injury; the only thing to avoid being distortion. The whole knack of packing birds corresponds to that of filling a trunk solidly full of clothes, as may easily be done without damage to an immaculate shirt-front. Finally, I would say, never put away a bird unlabelled, not even for an hour; you may forget it or die. Never tie a label to a bird's bill, wing, or tail; tie it securely to legs where they cross, and it will be just half as liable to become detached as if tied to one leg only. Never paste a label, or even a number, on a bird's plumage. Never put in glass eyes before mounting. Never paint or varnish a bird's bill or feet. Never replace missing plumage of one bird with the feathers of another—no, not even if the birds came out of the same nest.[1]

[1] [In presenting anew, and to an English public, the foregoing directions for manipulation, the author may be pardoned if he alludes to the test of time in their favour. Some of his earliest specimens, made in 1857, are extant, and in good order still. Many of the large cabinets, both in Europe and the United States, include some of his preparations, received in exchange through the Smithsonian Institution, or through private channels. They will be found, as a rule, compact yet shapely, with a smooth finish, and very durable. He may add, lest this paragraph should be misunderstood,

(b) Special Processes; Complications and Accidents

The Foregoing Method of procedure is a routine practice applicable to the "general run" of birds. But there are several cases requiring a modification of this process; while several circumstances may tend to embarrass operations. The principal special conditions may therefore be separately treated to advantage.

Size.—Other things being equal, a large bird is more difficult to prepare than a small one. In one case, you only need a certain delicacy of touch, easily acquired and soon becoming mechanical; in the other, demand on your strength may be made, till your muscles ache. It takes longer, too;[1] I could put away a dozen sparrows in the time I should spend over an eagle; and I would rather undertake a hundred humming-birds than one ostrich. For large birds, say anything from a hen-hawk upward, various special manipulations I have directed may be forgone, while however you observe their general drift and intent. You may open the bird as directed, or, turning it tail to you, cut with a knife.[2] Forceps are rarely required; there is not much that is too small to be taken in hand. As soon as the tail is divided, hang up the bird by the

that he has seldom purchased a birdskin, never sold one in his life, and for some years has owned none. Excepting a few given to friends, his ornithological specimens, as well as those in other departments of natural history, have always been presented to the United States Government, and deposited in the national collection at Washington. 9th September 1889.]

[1] The reader may be curious to know something of the statistics on this score—how long it ought to take him to prepare an ordinary skin. He can scarcely imagine, from his first tedious operations, how expert he may become, not only in beauty of result, but in rapidity of execution. I have seen taxidermists make good small skins at the rate of ten an hour; but this is extraordinary. The quickest work I ever did myself was eight an hour, or an average of seven and a half minutes apiece, and fairly good skins. But I picked my birds, all small ones, well shot, labelled, measured, and plugged beforehand, so that the rate of work was exceptional, besides including only the actual manipulations from first cut to laying away. No one averages eight birds an hour, even excluding the necessary preliminaries of cleansing, plugging, etc. Four birds an hour, everything included, is good work. A very eminent ornithologist of America, and an expert taxidermist, once laid a whimsical wager that he would skin and stuff a bird before a certain friend of his could pick all the feathers off a specimen of the same kind. I forget the time, but he won, and his friend ate crow, literally, that night.

[2] Certain among larger birds are often opened elsewhere than along the belly, with what advantage I cannot say from my own experience. Various water-birds, such as loons, grebes, auks, gulls, and ducks (in fact any swimming-bird with dense under plumage), may be opened along the side by a cut under the wings from the shoulder over the hip to the rump; the cut is completely hidden by the make-up, and the plumage is never ruffled. But I see no necessity for this; for, as a rule, the belly-opening can be completely effaced with due care, though a very greasy bird with white under plumage generally stains where opened, in spite of every precaution. Such birds as loons, grebes, cormorants, and penguins are often opened by a cut across the fundament from one leg to the other; their conformation in fact suggests and favours this operation. I have often seen water-birds slit down the back; but I consider it poor practice.

point is necessary for all large or medium-sized birds with naturally prominent legs. The stout finely feathered legs of a hawk, for example, ought to be well displayed; with these birds, and also with rails, etc., moreover, imitate the bulge of the thigh with a special wad laid inside the skin. Large birds commonly require also a special wad introduced by the mouth, to make the swell of the throat; this wad should be rather fluffy than firm. As a rule, do not fill out large birds to their natural dimensions; they take up too much room. Let the head, neck, and legs be accurately prepared, but leave the main cavity one-third if not one-half empty; no more stuffing is required than will fairly smooth out creases in the skin. Reduce bulk rather by flattening out than by general compression. Use tow instead of cotton; and if at all short of tow, economise with paper, hay, etc., at least for the deeper portions of the main stuffing. Large birds may be set in a great quantity of tow; wrapped in paper, much like any other parcel; or simply left to dry on the table, the wings being only supported by cushioning or other suitable means.

Shape.—Some special configurations have been noticed in the last paragraph, prematurely perhaps, but leading directly up to further considerations respecting shape of certain birds as a modifying element in the process of preparation. As for skinning, there is one extremely important matter. Most ducks, many woodpeckers, flamingoes, and some others, cannot be skinned in the usual way, because the head is too large for the calibre of the neck and cannot be drawn through. In such cases, skin as usual to the base of the skull, cut off the head there (inside the skin of course), and operate upon it, after turning the skin right side out, as follows: Part the feathers carefully in a straight line down the back of the skull, make a cut through the skin, just long enough to permit the head to pass, draw out the skull through this opening, and dress it as already directed. Return it, draw the edges of the cut nicely together, and sew up the opening with a great many fine stitches. Simple as it may appear, this process is often embarrassing, for the cut has an unhappy tendency to wander about the neck, enlarging itself even under the most careful manipulation; while the feathers of the parts are usually so short that it is difficult to efface all traces of the operation. I consider it very disagreeable; but for ducks I know of no alternative. I have, however, found out a way to avoid it with woodpeckers, excepting the very largest; it is this: Before skinning, part the eyelids, and plunge the scalpel right into the eyeball; seize the cut edge of the ball with the forceps, and pull the eye right out. It may be dexterously done without spilling the eye-water on the plumage; but, for fear of this, previously put a little gypsum on the spot. Throw arsenic into the

socket, and then fill it with cotton poked in between the lids. The eyes are thus disposed of. Then, in skinning, when you come to the head, dissever it from the neck and work the skull as far out as you can; it may be sufficiently exposed, in all cases, for you to gouge out the base of the skull with the scissors, and get at the brain to remove it. Apply an extra large dose of arsenic, and you will never hear from what jaw-muscle has been left in. In all these cases, as already remarked, the head is preferably set lying on one side, with the bill pointing obliquely to the right or left. Certain birds require a special mode of setting; these are, birds with very long legs or neck, or both, as swans, geese, pelicans, cormorants, snakebirds, loons, and especially cranes, herons, ibises, and flamingoes. Long legs should be doubled completely on themselves by bending at the heel-joint, and either tucked under the wings or laid on the under surface; the chief point is to see that the toes lie flat, so that the claws do not stick up, to catch in things or get broken off. A long neck should be carefully folded; not at a sharp angle with a crease in the skin, but with a short curve, and brought round either to the side of the bird or on its breast, as may seem most convenient. The object is to make a bale of the skin as nearly as may be, and when it is properly effected it is surprising what little space a crane, for instance, occupies. But it is rarely, if ever, admissible to bend a tail back on the body, however inconveniently long it may be. Special dilations of skin, like the pouch of a pelican, or the air-sacs of a prairie-hen, may be moderately displayed.

Thin Skin.—Loose Plumage.—It is astonishing how much resistance is offered by the thin skin of the smallest bird. Though no thicker than tissue paper, it is not very liable to tear if deftly handled; yet a rent once started often enlarges to an embarrassing extent if the skin be stretched in the least. Accidental rents and enlargements of shot-holes should be neatly sewn up, if occurring in an exposed place; but in most cases the plumage may be set to hide the openings. The trogons are said to have remarkably thin and delicate skin; I have never handled one in the flesh. Among British birds, the species of *Caprimulgidæ* have about the tenderest skins. The obvious indication in all such cases is simply a little extra delicacy of manipulation. In skinning most birds, you should not lose more than a feather or two, excepting those loosened by the shot. Pigeons are peculiar for the very loose insertion of their plumage; you will have to be particularly careful with them, and in spite of all your precautions a good many feathers will probably drop. As stripping down the secondary quills from the fore-arm, in the manner already indicated, will almost invariably set these feathers free from the skin, I recommend you not to attempt it, but to dress the wings as prescribed for large birds.

Fatness.—Fat is a substance abhorred of all dissectors; always in the way, embarrassing operations and obscuring observations; while it is seldom worth examination after its structure has once been ascertained. It is particularly obnoxious to the taxidermist, since it is liable to soil the plumage during skinning, and also to soak into the feathers afterwards; and greasy birdskins are never pleasing objects. A few birds never seem to have any fat; some, like petrels, are always oily; at times, especially in the indolent autumn season, when birds have little to do but feed, the great majority acquire an *embonpoint* doubtless to their own satisfaction, but to the taxidermist's discomfort. In all such cases gypsum should be lavishly employed. Strew plaster plentifully from the first cut all through the operation; dip your fingers in it frequently, as well as your instruments. This invaluable absorbent will deal with most of the running fat. When the skin is completely reversed, remove as much of the solid fat as possible; it is generally found occupying the areolar tissue of particular definite tracts, and most of it may usually be peeled or flaked off in considerable masses. Since the soft and oozy state of most birds' fat at ordinary temperatures may be much improved by cold, it will be well to leave your birds on ice for a while before skinning, if you have the means and time to do so; the fat will become quite firm. There is a device for preventing or at any rate lessening the soiling of the plumage so apt to occur along the line of incision; it is invaluable in cases of white plumage. Take a strip of cloth of greater width than the length of the feathers, long enough to go up one side of the cut and down the other. Sew this closely to the skin all around the cut, and it will form an apron to guard the plumage. You will too frequently find that a bird, prepared without soiling and laid away apparently safe, afterwards grows greasy; if the plumage is white, it soon becomes worse than ever by showing dust that the grease catches. Perhaps the majority of such birds in our museums show the dirty streak along the belly. The reason is, that the grease has oozed out along the cut, or wherever else the skin has been broken, and infiltrated the plumage, being drawn up apparently by capillary attraction, just as a lampwick sucks up oil. Sometimes, without obviously soiling the plumage, the grease will run along the thread that ties the label, and make a uniformly transparent piece of oil-paper. I have no remedy to offer for this gradual infiltration of the plumage. It will not wash out, even with soap and water. Possibly careful and persistent treatment with ether might be effective, but I am not prepared to say it would be. Removal of all fat that can be got off during skinning, with a liberal use of plaster, will in a measure prevent a difficulty that remains incurable.

Bloodstains, etc.—In the nature of the case, this complication

is of continual occurrence; fortunately it is easier dealt with than greasiness. Much may be done in the field to prevent bloodying of the plumage, as already said. A little blood does not show much on a dark plumage; but it is of course conspicuous on light or white feathers. Dried blood may often be scraped off, in imitation of the natural process by which a bird cleanses its plumage with the bill; or be pulverised by gently twiddling the feathers between the fingers, and then blown off. But feathers may by due care be *washed* almost as readily as clothing; and we must ordinarily resort to this to remove all traces of blood, especially from white surfaces. If properly dried they do not show the operation. With a soft rag or pledget of cotton dipped in warm water bathe the place assiduously, pressing down pretty hard, only taking care to stroke the feathers the right way, so as not to crumple them, until the red colour disappears; then you have simply a wet place to deal with. Press gypsum on the spot; it will cake; flake it off and apply more, till it will no longer stick. Then raise the feathers on a knife-blade and sprinkle gypsum in among them; pat it down and shake it up, till the moisture is entirely absorbed. Two other fluids of the body will give occasional annoyance,—the juices of the alimentary canal and the eye-water. Escape of the former by mouth, nostrils, or vent is preventable by plugging these orifices, and its occurrence is inexcusable. But shot often lacerates the gullet, crop, and bowels, and though nothing may flow at the time, subsequent jolting or pressure in the game-bag causes the escape of fluids: a seemingly safe specimen may be unwrapped to show the whole belly-plumage a sodden brown mass. Such accidents should be treated precisely like bloodstains; but it is to be remarked that these stains are not seldom indelible, traces usually persisting, in white plumage at least, in spite of our best endeavours. Eye-water, insignificant as it may appear, is often a great annoyance. This liquor is slightly glairy, or rather glassy, and puts a sort of sizing on the plumage difficult to efface; the more so since the soiling necessarily occurs in a conspicuous place, where the plumage is scanty and delicate. It frequently happens that a lacerated eyeball, by the elasticity of the coats, or adhesion of the lids, retains its fluid till this is pressed out in manipulating the parts; and, recollecting how the head lies buried in plumage at that stage of the process, it will be seen that not only the head, but much of the neck and even the breast, may become wetted. If the parts are extensively soaked, the specimen is almost irreparably damaged. Plaster will absorb the moisture, but much of the sizing may be retained on the plumage; therefore, though the place seems simply wet, it should be thoroughly washed with water before the gypsum is applied. I always endeavour to prevent the accident; if I notice a lacerated eyeball, I extract it

before skinning, in the manner described for woodpeckers. Miscellaneous stains, from the juices of plants, etc., may be received; all such are treated on general principles. Blood on the beak and feet of rapacious birds, mud on the bill and legs of waders, etc. etc., may be washed off without the slightest difficulty. A land bird that has fallen in the water should be recovered as soon as possible, picked up by the bill, and shaken; most of the water will run off, unless the plumage is completely soaked. It should be allowed to dry just as it is, without touching the plumage, before being wrapped and bagged. If a bird fall in soft mud, the dirt should be scraped or snapped off as far as this can be done without plastering the feathers down, and the rest allowed to dry; it may afterward be rubbed fine and dusted off, when no harm will ensue, except to white feathers, which may require washing.

Mutilation.—You will often be troubled, early in your practice, with broken legs and wings, and various lacerations; but the injury must be very severe (such as the carrying away of a limb, or blowing off the whole top of a head) that cannot be in great measure remedied by care and skill. Suppose a little bird, shot through the neck or small of the back, comes apart while being skinned; you have only to remove the hinder portion, be that much or little, and go on with the rest as if it were the whole. If the leg-bone of a small bird be broken near the heel, let it come away altogether; it will make little if any difference. In case of the same accident to a large bird that ought to have the legs wrapped, whittle out a peg and stick it in the hollow stump of the bone; if there is no stump left, file a piece of stout wire to a point and stick it into the heel joint. If the fore-arm bone that you usually leave in a small bird is broken, remove it and leave the other in; if both are broken, do not clean the wings so thoroughly that they become detached; an extra pinch of arsenic will condone the omission. In a large bird, if both bones of the fore-arm are broken, splint them with a bit of wood laid in between, so that one end hitches at the elbow, the other at the wrist. A humerus may be replaced like a leg bone, but this is rarely required. If the skull be smashed, save the pieces, and leave them if you can; if not, imitate the arch of the head with a firm cotton-ball. A broken tarsus is readily splinted with a pin thrust up through the sole of the foot; if too large for this, use a pointed piece of wire. There is no mending a bill when part of it is shot away; for I think the replacing of part by putty, stucco, etc., inadmissible; but if it be only fractured, the pieces may usually be retained in place by winding with thread, or with a touch of glue or mucilage. I have already hinted how artfully various weak places in a skin, due to mutilation or loss of plumage, may be hidden.

Decomposition.—It might seem unnecessary to speak of what may be smelt so readily as animal putrescence; but there are some useful points to be learned in this connection, besides the important sanitary precautions that are to be deduced. Immediately after death the various fluids of the body begin to settle (so to speak), and shortly afterward the muscular system becomes fixed in what is technically called *rigor mortis*. This stiffening usually occurs as the animal heat dies away; but its onset, and especially its duration, is very variable, according to circumstances, such as cause of death; although in most cases of sudden violent death of an animal in previous good health, it seems to depend chiefly upon temperature, being transient and imperfect, or altogether wanting, in hot weather. As it passes off, the whole system relaxes, and the body soon becomes as limp as at the moment of death. This is the period immediately preceding decomposition; in fact, it may be considered as the stage of incipient putridity; it is very brief in warm weather, and it should be seized as the last opportunity of preparing a bird without inconvenience and even danger. If not skinned at once, putrescence becomes established; it is indicated by the effluvium; by the distension of the abdomen with gaseous products of decomposition; by the loosening of the cuticle, and consequently of the feathers; and by other signs. If you part the feathers of a bad-smelling bird's belly to find the skin swollen and livid or greenish, while the feathers come off at a touch, the bird is too far gone to be recovered without trouble and risk that no ordinary specimen warrants. It is a singular fact that this early putrescence is more poisonous than utter rottenness; as physicians are aware, a *post-mortem* examination at this stage, or even before it, involves more risk than their ordinary dissecting-room experience. It seems that both natural and pathological poisons lose their early virulence by resolution into other products of decay. The obvious deduction from this is to skin your birds soon enough. Some say they are best skinned perfectly fresh, but I see no reason for this; when I have time to choose, I take the period of rigidity as being preferable on the whole; for the fluids have then settled, and the limbs are readily relaxed by manipulation. If you have a large bag to dispose of, and are pressed for time, set them in the coolest place you can find, preferably on ice; a slight lowering of temperature may make a decided difference. Disembowelling, which may be accomplished in a moment, will materially retard decomposition. Injections of creosote or dilute carbolic acid will arrest decay for a time, or for an indefinitely long period if a large quantity of these antiseptics be employed. When it becomes desirable (it can never be necessary) to skin a putrescent bird, great care must be exercised not only to accomplish the operation, but to avoid danger. I must

not, however, lead you to exaggerate the risk, and will add that I think it often overrated. I have probably skinned birds as "gamey" as any one has, and repeatedly, without being conscious of any ill effects. I am sure that no poison, ordinarily generated by decomposition of a body healthy at death, can compare in virulence with that commonly resulting after death by many diseases. I also believe that the gaseous products, however offensive to the smell, are innocuous as a rule. The danger practically narrows down to the absorption of fluids through an abraded surface; the poison is rarely taken in by natural pores of healthy skin, if it remain in contact but a short time. Cuts and scratches may be closed with a film of collodion, or covered with isinglass or court-plaster, or protected by rubber cots on the fingers. The hands should, of course, be washed with particular care immediately after the operation, and the nails scrupulously dressed. Having never been poisoned, I cannot give the symptoms from personal experience; but I will quote from Mr. Maynard:—

"In a few days numerous pimples, which are exceedingly painful, appear upon the skin of the face and other parts of the person, and, upon those parts where there is chafing or rubbing, become large and deep sores. There is a general languor, and, if badly poisoned, complete prostration results; the slightest scratch becomes a festering sore. Once poisoned in this manner (and I speak from experience), one is never afterward able to skin any animal that has become in the least putrid, without experiencing some of the symptoms above described. Even birds that you handled before with impunity you cannot now skin without great care. The best remedy in this case is, as the Hibernian would say, not to get poisoned . . . bathe the parts frequently in cold water; and, if chafed, sprinkle the parts after bathing with wheat flour. These remedies, if persisted in, will effect a cure, if not too bad; then, medical advice should be procured without delay."

My advice would be, to avoid all mechanical irritation of the inflamed parts; touch the parts that have ulcerated with a stick of lunar caustic; take a dose of salts; use syrup of the iodide of iron, or tincture of the chloride of iron, say thirty drops of either, in a wineglass of water, thrice daily; rest at first, exercise gradually as you can bear it; and skin no birds till you have completely recovered.

How to mount Birds.—As some may not improbably procure this volume with a reasonable expectation of being taught to mount birds, I append the required instructions, although I only profess to treat of the preparation of skins for the cabinet. As a rule, the purposes of science are best subserved by not mounting specimens; for display, the only end attained, is not required. I would

strongly advise you not to mount your rarer or otherwise particularly valuable specimens; select for this purpose nice, pretty birds of no special scientific value. The principal objections to mounted birds are, that they take up too much room, require special arrangements for keeping and transportation, and cannot be handled for study with impunity. Some might suppose that a mounted bird would give a better idea of its figure and general aspect than a skin; but this is only true to a limited extent. Faultless mounting is an art really difficult, acquired by few; the average work done in this line shows something of caricature, ludicrous or repulsive, as the case may be. To copy nature faithfully by taxidermy requires not only long and close study, but an artistic sense; and this last is a rare gift. Unless you have at least the germs of the faculty in your composition, your taxidermal success will be incommensurate with the time and trouble you bestow. My own taxidermal art is of a low order, decidedly not above average; although I have mounted a great many birds that would compare very favourably with ordinary museum work, few of them have entirely answered my ideas. A live bird is to me such a beautiful object that the slightest taxidermal flaw in the effort to represent it is painfully offensive; perhaps this makes me place the standard of excellence too high for practical purposes. I like a good honest birdskin that does not pretend to be anything else; it is far preferable to the ordinary taxidermal abortions of the show-cases. But if, after the warnings that I mean to convey in this paragraph, you still wish to try your hand in the higher department of taxidermy, I will explain the whole process as far as manipulation goes; the art you must discover in yourself.

The operation of skinning is precisely the same as that already given in detail; then, instead of stuffing the skin as directed above, to lie on its back in a drawer, you have to stuff it so that it will stand up on its feet and look as much like a live bird as possible. To this end a few additional implements and materials are required. These are: (*a*) annealed wire of various numbers; it may be iron, copper, or brass, but must be perfectly annealed, so as to retain no elasticity or spring; (*b*) several files of different sizes; (*c*) some slender straight brad-awls; (*d*) cutting pliers; (*e*) setting needles, merely sewing or darning needles stuck in a light wooden handle, for dressing individual feathers; (*f*) plenty of pins (the long, slender insect pins used by entomologists are the best) and sewing thread; (*g*) an assortment of glass eyes. (The fixtures and decorations are noticed, beyond, as occasion for their use arises.)

There are two principal methods of mounting, which may be respectively styled *soft* stuffing and *hard* stuffing. In the former, a wire framework, consisting of a single anterior piece passing in the

middle line of the body up through the neck and out at the top of the head, is immovably joined behind with two pieces, one passing through each leg; around this naked forked frame soft stuffing is introduced, bit by bit, till the proper contour of the skin is secured. I have seen very pretty work of this kind, particularly on small birds; but I consider it much more difficult to secure satisfactory results in this way than by hard stuffing, and I shall therefore confine attention to the latter. This method is applicable to all birds, is readily practised, facilitates setting of the wings, arranging of the plumage, and giving of any desired attitude. In hard stuffing, you make a firm ball of tow rolled upon a wire of the size and shape of the bird's body and neck together; you introduce this whole, afterwards running in the leg wires and clinching them immovably in the mass of tow.

Having your empty skin in good shape, as already described, cut three pieces of wire of the right[1] size; one piece somewhat longer than the whole bird, the other pieces two or three times as long as the whole leg of the bird. File one end of each piece to a fine sharp point; try to secure a three-edged cutting point like that of a surgical needle, rather than the smooth punching point of a sewing-needle, as the former perforates more readily. Have these wires perfectly straight.[2] Bend a small portion of the unfiled end of the longer wire irregularly upon itself, as a convenient nucleus for the ball of tow.[3] Take fine clean tow, in loose dossils, and wrap it round and round the wire nucleus, till you make a firm ball, of the size and shape of the bird's body and neck. Study the contour of the skinned body: notice the swelling breast-muscles, the arch of the lower back, the hollow between the forks of the merrythought into which the neck, when naturally curved, sinks. Everything depends upon correct shaping of the artificial body; if it be misshapen, no art can properly adjust the skin over it. Firmness of the tow ball and accurate contour may both be secured by wrapping the mass with sewing thread, loosening here, tightening there, till the shape is satisfactory. Be particular to secure a smooth surface; the skin in drying will shrink close to the stuffing, disclosing its irregularities, if there be any, by the maladjustment of the plumage that will ensue. Observe especially that the neck, though the direct continuation of the backbone, dips at its lower

[1] The right size is the smallest that will support the whole weight of the stuffing and skin without bending, when a piece is introduced into each leg. If using too thick wire, you may have trouble in thrusting it through the legs, or may burst the tarsal envelope.

[2] If accidentally kinky, the finer sizes of wire may be readily straightened by drawing strongly upon them so as to stretch them a little. Heavier wire must be hammered out straight.

[3] Cotton will not do at all; it is too soft and elastic, and moreover will not allow of the leg wires being thrust into it and there clinched.

end into the hollow of the merrythought, and so virtually begins there instead of directly between the shoulders. The three mistakes most likely to be made by a beginner are, getting the body altogether too large, not firm enough, and irregular. When properly made, it will closely resemble the bird's body and neck, with an inch or several inches of sharp-pointed wire protruding from the anterior extremity of the neck of tow. You have now to introduce the whole affair into the skin. With the birdskin on its back, the tail pointing to your right elbow, and the abdominal opening as wide as possible, *hold the tow body in position relative to the skin;* enter the wire, pass it up through the neck, bring the sharp point exactly against the middle of the skull, pierce skull and skin, causing the wire to protrude some distance from the middle of the crown. Then by gentle means insinuate the body, partly pushing it in, partly drawing the skin over it, till it rests in its proper position. This is just like drawing on a tight kid glove, and no more difficult. See that the body is completely encased; you must be able to close the abdominal aperture entirely. You have next to wire the legs. Enter the sharp point of one of the leg-wires already prepared, exactly at the centre of the sole of the foot, thrusting it up inside the tarsal envelope the whole length of the shank, thence across the heel-joint[1] and up along the next bone of the leg, still inside the skin. The point of the wire will then be seen within the skin, and may be seized and drawn a little farther through, and you will have passed a wire entirely out of sight all the way along the leg. The end of the wire is next to be fixed immovably in the tow ball. Thrust it in at the point where the knee, in life, rests against the side of the body.[2] Bring the point to view, bend it over and reinsert it till it sticks fast. There are no special directions to be given here; fasten the wire in any way that effectually prevents wabbling. You may find it convenient to wire both legs before fastening either, and then clinch them by twisting the two ends together. But remember that the leg-wires may be fixed respecting each other, yet permit a see-saw motion of the body upon them. This must not be; the body and legs must be fixed upon a jointless frame. Having secured the legs, close the abdominal opening nicely, either by sewing or pinning; you may stick pins in anywhere, as freely as in a pin-cushion; the feathers

[1] There is occasionally difficulty in getting the wire across this joint, from the point sticking into the enlarged end of the shin-bone. In such case, take stout pliers and pinch the joint till the bone is smashed to fragments. The wire will then pass and the comminution will not show. If there is any trouble in passing the wire through the tarsus, bore a hole for it with a brad-awl.

[2] This point is farther forward and more belly-ward than you might suppose. Observe the skinned body again, and see where the lower end of the thigh lies. If you insert the wire too far back, you cannot by any possibility balance the bird naturally on its perch; it will look in imminent danger of toppling over.

hide their heads. Stick a pin through the pope's-nose to fix the tail in place.

All this while the bird has been lying on its back, the neck *stretched straight* in continuation of the body, wired stiffly, the legs *straddling* wide apart, straight and stiff, the wings lying loosely, *half-spread*. Now bring the legs together, parallel with each other, and make the sharp bend at the heel-joint that will bring the feet naturally under the belly (over it, as the bird lies on its back). Pick up the bird by the wires that project from the soles and set it on its stand, by running the wires through holes bored the proper distance apart, and then securing the ends by twisting. The temporary stand that you use for this purpose should have a heavy or otherwise firm support, so as not easily to overturn during the subsequent manipulations. At this stage the bird is a sorry-looking object; but if you have stuffed correctly and wired securely, it will soon improve. Begin by making it stand properly. The common fault here is placing the tarsi too nearly perpendicular. Perching birds, constituting the majority, habitually stand with the tarsi more nearly horizontal than perpendicular, and generally keep the tarsi parallel with each other. Wading and most walking birds stand with the legs more nearly upright and straight. Many swimming birds straddle a little; others rarely if ever. See that the toes clasp the perch naturally, or are properly spread on the flat surface. Cause the flank feathers to be correctly adjusted over the tibiæ (and here I will remark that with most birds little, if any, of the tibiæ shows in life), the heel-joint barely, if at all, projecting from the general plumage. It is a common fault of stuffing not to draw the legs closely enough to the body. Above all, look out for the centre of gravity; though you have really fastened the bird to its perch, you must not let it look as if it would fall off if the wires slipped; it must appear to rest there of its own accord. Next, give the head and neck a preliminary setting, according to the attitude you have determined upon. This will bring the plumage about the shoulders in proper position for the setting of the wings, to which you may at once attend. If the body be correctly fashioned and the skin of the shoulders duly adjusted over it, the wings will fold into place without the slightest difficulty. All that I have said before about setting the wings in a skin applies here as well; but in this case they will not *stay* in place, since they fall by their own weight. They must be pinned up. Holding the wing in place, thrust a pin steadily through near the wrist-joint, into the tow body. Sometimes another pin is required to support the weight of the primaries; it may be stuck into the flank of the bird, the outer quill feather resting directly upon it. With large birds a sharp pointed wire must replace the pin. When properly set, the wing-tips will fall

together or symmetrically opposite each other, the quills' and coverts will be smoothly imbricated, the scapular series of feathers will lie close, and no bare space will show in front of the shoulder. Much depends upon the final adjustment of the head. The commonest mistake is getting it too far away from the body. In the ordinary attitudes of most birds little neck shows, the head appearing nestled upon the shoulders. If the neck appears too long, it is not to be contracted by pushing the head directly down upon it, but by making an S curve of the neck. No precise directions can be given for the set of the head, but you may be assured it is a delicate, difficult matter; the slightest turn of the bill one way or another may alter the whole expression of the bird. You will of course have determined beforehand upon your attitude, upon what you wish the bird to appear to be doing; then, let your meaning be pointed by the bird's bill.

On the general subject of striking an attitude, and giving expression to a stuffed bird, little can be said to good purpose. If you are to become proficient in this art, it will come from your own study of birds in the field, your own good taste and appreciation of bird-life. The manual processes are easily described and practised; it is easy to grind paint, I suppose, but not so to be an artist. I shall therefore only follow the above account of the general processes with some special practical points. After "attitudinising" to your satisfaction, or to the best of your ability, the plumage is to be carefully dressed. Feathers awry may be set in place with a light spring forceps, or needles fixed in a handle, one by one if necessary. When no individual feather seems out of place, it often occurs that the general plumage has a loose, slovenly aspect. This is readily corrected by wrapping with fine thread. Stick a pin into the middle of the back, another into the breast, and perhaps others elsewhere. Fasten the end of a spool of sewing cotton to one of the pins, and carry it to another, winding the thread about among the pins, till the whole surface is covered with an irregular network. Tighten to reduce an undue prominence, loosen over a depression; but let the wrapping as a whole be light, firm, and even. This procedure, nicely executed, will give a smoothness to the plumage not otherwise attainable, and may be made to produce the most exquisite curves, particularly about the head, neck, and breast. The thread should be left on till the bird is perfectly dry; it may then be unwound or cut off, and the pins withdrawn. When a particular patch of skin is out of place, it may often be pulled into position and pinned there. You need not be afraid of sticking pins in anywhere: they may be buried in the plumage and left there, or withdrawn when the skin is dry. In addition to the main stuffing, a little is often required in particular

places. As for the legs, they should be filled out in all such cases as I indicated earlier in this section; small birds require no such stuffing. It is necessary to fill out the eyes so that the lids rest naturally; it may be done as heretofore directed, or by putting in pledgets of cotton from the outside. A little nice stuffing is generally required about the upper throat.

To stuff a bird with spread wings requires a special process, in most cases. The wings are to be wired, exactly as directed for the legs; they may then be placed in any shape. But with most small birds, and those with short wings, simple pinning in the half-spread position indicating fluttering will suffice; it is readily accomplished with a long, slender insect pin. I have already spoken of fixing the tail by pinning or wiring the pope's-nose to the tow body; it may be thus fixed at any desired elevation or depression. There are two ways of spreading the tail. One is to run a pointed wire through the quills, near their base, where the wire will be hidden by the coverts; each feather may be set at any required distance from the next by sliding it along this wire. This method is applicable to large birds; for small ones the tail may be fixed with the desired spread by enclosing it near its base in a split match, or two slips of cardboard, with the ends tied together. This holds the feathers until they dry in position, when it is to be taken off. Crests may be raised, spread, and displayed on similar principles. A small crest, like that of a cardinal or cherry bird, for instance, may be held up till it dries in position by sticking in behind it a pin with a little ball of cotton on its head. It is sometimes necessary to make a bird's toes grasp a support by tying them down to it till they dry. The toes of waders that do not lie evenly on the surface of the stand may be tacked down with small brads. The bill may be pinned open or shut, as desired, by the method already given.

Substitution of an artificial eye for the natural one is essential for the good looks of a specimen. Glass eyes, of all sizes and colours, may be purchased at a moderate cost. The pupil is always black; the iris varies. You will, of course, secure the proper colour if it is known, but if not, put in a dark brown or black eye. It is well understood that this means nothing; it is purely conventional. Yellow is probably the next most common colour; then come red, white, blue, and green, perhaps approximately in this order of frequency. But do not use these striking colours at haphazard; sacrificing truth, perhaps, to looks. Eyes are generally inserted after the specimen is dry. Remove a portion of the cotton from the orbit, and moisten the lids till they are perfectly pliable; fix the eye in with putty or wet plaster of Paris, making sure that the lids are naturally adjusted over it. It goes in obliquely, like a

button through a button-hole. Much art may be displayed in this little matter, making a bird look this way or that, to carry out the general expression.

On finishing a specimen, set it away to dry; the time required varies, of course, with the weather, the size of the bird, its fatness, etc. The more slowly it dries, the better; there is less risk of the skin shrinking irregularly. You will often find that a specimen set away with smooth plumage and satisfactory curves dries more or less out of shape, perhaps with the feathers raised in places. I know of no remedy; it may, in a measure, be prevented by scrupulous care in making the body smooth and firm, and in securing slow, equable drying. When perfectly dry remove the wrapping, pull out the superfluous pins or wires, nip off the others so short that the ends are concealed, and insert the eyes. The specimen is then ready to be transferred to its permanent stand.

Fixtures for the display of the object of course vary interminably. We will take the simplest case, of a large collection of mounted birds for public exhibition. In this instance, uniformity and simplicity are desirable. "Spread eagle" styles of mounting, artificial rocks and flowers, etc., are entirely out of place in a collection of any scientific pretensions, or designed for popular instruction. Besides, they take up too much room. Artistic grouping of an extensive collection is usually out of the question; and when this is unattainable, half-way efforts in that direction should be abandoned in favour of severe simplicity. Birds look best on the whole in uniform rows, assorted according to size, as far as a natural classification allows. They are best set on the plainest stands, with circular base and a short cylindrical crossbar on a lightly turned upright. The stands should be painted dead-white, and be no larger than is necessary for secure support; a neat stiff paper label may be attached. A small collection of birds, as an ornament to a private residence, offers a different case; here variety of attitude and appropriate imitation of the birds' natural surroundings are to be secured. A miniature tree, on which a number of birds may be placed, is readily made. Take stout wire, and by bending it, and attaching other pieces, get the framework of the tree of the desired size, shape, and number of perches. Wrap it closely with tow to a proper calibre, remembering that the two forks of a stem must be together only about as large as the stem itself. Gather a basketful of lichens and tree moss; reduce them to coarse powder by rubbing with the hands; besmear the whole tree with mucilage or thin glue, and sift the lichen powder on it till the tow is completely hidden. This produces a very natural effect, which may be heightened by separately affixing larger scraps of lichen, or little bunches of moss; artificial leaves and flowers

may be added at your taste. The groundwork may be similarly prepared with a bit of board, made adhesive and bestrewn with the same substance; grasses and moss may be added. If a flat surface is not desired, soak stout pasteboard till it can be moulded in various irregular elevations and depressions; lay it over the board and decorate it in the same way. Rocks may be thus nicely imitated, with the addition of powdered glass of various colours. Such a lot of birds is generally enclosed in a cylindrical glass case with arched top. As it stands on a table to be viewed from different points, it must be presentable on all sides. A niche in parlour or study is often fitted with a wall-case, which, when artistically arranged, has a very pleasing effect. As such cases may be of considerable size, there is opportunity for the display of great taste in grouping. A place is not to be found for a bird, but a bird for the place,—waders and swimmers below on the ground, perchers on projecting rests above. The surroundings may be prepared by the methods just indicated. One point deserves attention here: since the birds are only viewed from the front, they may have a "show-side" to which everything else may be sacrificed. Birds are represented flying in such cases more readily than under other circumstances, supported on a concealed wire inserted in the back of the case. I have seen some very successful attempts to represent a bird swimming, the duck being let down part way through an oval hole in a plate of thick glass, underneath which were fixed stuffed fishes, shells, and seaweed. It is hardly necessary to add that in all ornamental collections, labels or other scientific machinery must be rigorously suppressed.

Transportation of mounted birds offers obvious difficulty. Unless very small, they are best secured immovably inside a box by screwing the foot of the stands to the bottom and sides, so that they stay in place without touching each other. Or, they may be carefully packed in cotton, with or without removal of the stands. Their preservation from accidental injury depends upon the same care that is bestowed upon ordinary fragile ornaments of the parlour. The ravages of insects are to be prevented upon the principles to be hereafter given in treating of the preservation of birdskins.

§ 8.—MISCELLANEOUS PARTICULARS

Determination of Sex.—This is an important matter, which should never be neglected. For although many birds show unequivocal sexual distinctions of size, shape, and colour, like those of

the barnyard cock and hen, for instance, yet the outward characteristics are more frequently obscure, if not altogether inappreciable, on examination of the skin alone. Young birds, moreover, are usually indistinguishable as to sex, although the adults of the same species may be easily recognised. The rule results, that the sexual organs should be examined as the only infallible indices. The essential organs of masculinity are the *testicles;* similarly, the *ovaries* contain the essence of the female nature. However similar the accessory sexual structures may be, the testicles and ovaries are always distinct. The male organs of birds never leave the cavity of the belly to fill an external bag of skin (*scrotum*) as they do among mammals; they remain within the abdomen, and lie in the same position as the ovaries of the female. Both these organs are situated in the belly opposite the "small of the back," bound closely to the spine, resting on the front of the kidneys near their fore end. The testicles are a pair of subspherical or rather ellipsoidal bodies, usually of the same size, shape, and colour, and are commonly of a dull opaque whitish tint. They always lie close together. A remarkable fact connected with them is, that they are not always of the same size in the same bird, being subject to periodical enlargement during the breeding season, and corresponding atrophy at other seasons. Thus the testicles of a house sparrow, no bigger than a pin's head in winter, swell to the size of peas in April. The ovary (for although this organ is paired originally, only one is usually functionally developed in birds) will be recognised as a flattish mass of irregular contour, and usually whitish colour; when inactive, it simply appears of finely granular structure which may require a hand lens to be made out; when producing eggs, its appearance is unmistakable. Both testis and ovary may further be recognised by a thread leading to the end of the lower bowel,—in one case the sperm-duct, in the other the oviduct; the latter is usually much the more conspicuous, as it at times transmits the perfect egg. There is no difficulty in reaching the site of these organs. Lay the bird on the left side, its belly toward you: cut with the scissors through the belly-walls diagonally from anus to the root of the last rib, or further, snipping across a few of the lower ribs, if these continue far down, as they do in a loon, for instance. Press the whole mass of intestines aside collectively, and you at once see to the small of the back. There you observe the *kidneys*,—large, lobular, dark reddish masses moulded into the concavity of the sacrum (or back middle bone of the pelvis); and on their surface, toward their fore end, lie testes or ovary, as just described. The only precaution required is, not to mistake for testicles a pair of small bodies capping the kidneys. These are the *adrenals* or suprarenal capsules,—organs whose function is unknown, but

with which at any rate we have nothing to do in this connection. They occur in both sexes, and if the testicles are not immediately seen, or the ovary not at once recognised, they might easily be mistaken for testicles. Observe that, instead of lying in front, they cap the kidneys; that they are usually yellowish instead of opaque whitish; and that they have not the firm, smooth, regular sphericity of the testicles. The testes, however, vary more in shape and colour than might be expected, being sometimes rather oblong or linear, and sometimes grayish or livid bluish, or reddish. There is occasionally but one. The sex determined, use the sign ♂ or ♀ to designate it, as already explained.

Recognition of Age is a matter of ornithological experience requiring in many or most cases great familiarity with birds for its even approximate accomplishment. There are, however, some unmistakable signs of immaturity, even after a bird has become full-feathered, that persist for at least one season. These are, in the first place, a peculiar soft fluffy feel of the plumage; the feathers lack a certain smoothness, density, and stiffening which they subsequently acquire. Secondly, the bill and feet are softer than those of the adults; the corners of the mouth are puffy and flabby, the edges and point of the bill are dull, and the scales, etc., of the legs are not sharply cut. Thirdly, the flesh itself is tender and pale coloured. These are some of the points common to all birds, and are independent of the special markings that belong to the youth of particular species. Some birds are actually larger for a while after leaving the nest than in after years when the frame seems to shrink somewhat in acquiring the compactness of senility. On the other hand, the various members, especially the bill and feet, are proportionally smaller at first. Newly growing quills are usually recognised on sight, the barrel being dark coloured and full of liquid, while the vanes are incomplete. In studying, for example, the shape of a wing or tail, there is always reason to suspect that the natural proportions are not yet presented, unless the quill is dry, colourless, and empty, or only occupied with shrunken white pith.

Examination of the Stomach frequently leads to interesting observations, and is always worth while. In the first place, we learn most unquestionably the nature of the bird's food, which is a highly important item in its natural history. Secondly, we often secure valuable specimens in other departments of zoology, particularly entomology. Birds consume incalculable numbers of insects, the harder kinds of which, such as beetles, are not seldom found intact in their stomachs; and a due percentage of these represent rare and curious species. The gizzards of birds of prey, in particular, should always be inspected, in search of the small mammals, etc., they devour; and even if the creatures are unfit for preservation,

we at least learn of their occurrence, perhaps unknown before in a particular region. Mollusk-feeding and fish-eating birds yield their share of specimens. The alimentary canal is often the seat of parasites of various kinds, interesting to the helminthologist; other species are to be found under the skin, in the body of muscle, in the brain, etc. Most birds are also infested with external parasites of many kinds, so various that almost every leading species has its own sort of louse, tick, etc. Since these creatures are only at home with a live host, they will be found crawling on the surface of the plumage, preparing for departure, as soon as the body cools after death. There is thus much to learn of a bird aside from what the prepared specimen teaches, and moreover apart from regular anatomical investigations. Whenever practicable, brief items should be recorded on the label, as already mentioned.

Restoration of Poor Skins.—If your cabinet be a general one, comprising specimens from various sources, you will frequently happen to receive skins so badly prepared as to be unpleasant objects, besides failing to show their specific characters. There is, of course, no supplying of missing parts or plumage; but if the defect be simply deformity, this may usually be in a measure remedied. The point is simply to relax the skin, and then proceed as if it were freshly removed from the bird; it is what bird-stuffers constantly do in mounting birds from prepared skins. The relaxation is effected by moisture alone. Remove the stuffing; fill the interior with cotton or tow saturated with water, yet not dripping; put pads of the same under the wings; wrap the bill and feet, and set the specimen in a damp, cool place. Small birds soften very readily and completely; the process may be facilitated by persistent manipulation. This is the usual method, but there is another, more thorough and more effective; it is exposure to a vapour-bath. The appointments of the kitchen stove furnish all the apparatus required for an extempore steamer; the regular fixture is a tin vessel much like a wash-boiler, with closed lid, false bottom, and stopcock at lower edge. On the false bottom is placed a heavy layer of gypsum, completely saturated with water; the birds are laid on a perforated tray above it; and a gentle heat is maintained over a stove. The vapour penetrates every part of the skin, and completely relaxes it, without actually wetting the feathers. The time required varies greatly of course; observation is the best guide. The chief precaution is not to let the thing get too hot. Professor Baird has remarked that crumpled or bent feathers may have much of their original elasticity restored by dipping in hot water. Immersion for a few seconds suffices, when the feathers will be observed to straighten out. Shaking off superfluous water, they may be simply left to dry, or they may be dried with plaster.

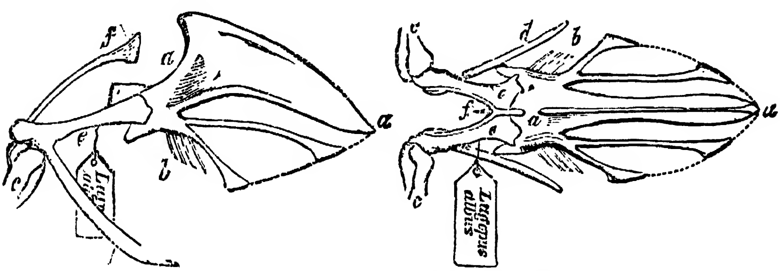
The method is chiefly applicable to the large feathers of the wings and tail. Soiled plumage of dried skins may be treated exactly as in the case of fresh skins.

Mummification.—As before mentioned, decay may be arrested by injections of carbolic acid and other antiseptics; if the tissues be sufficiently permeated with these substances, the body will keep indefinitely; it dries and hardens, becoming, in short, a mummy. Injection should be done by the mouth and vent, be thorough, and be repeated several times as the fluid dries in. It is an improvement on this to disembowel and fill the belly with saturated tow or cotton. Due care should be taken not to soil the feathers in any case, nor should the carbolic solution come in contact with the hands, for it is a powerful irritant poison. I mention the process chiefly to condemn it; I cannot imagine what circumstances would recommend it, while only an extreme emergency could justify it. It is further objectionable because it appears to lend a dingy hue to some plumages, and to dull most of them perceptibly. Birds prepared—rather unprepared—in this way, may be relaxed by the method just described, and then skinned; but the operation is difficult.

Wet Preparations.—By this term is technically understood an object immersed in some preservative fluid. It is highly desirable to obtain more information of birds than their stuffed skins can ever furnish, and their structure cannot be always examined by dissection on the spot. In fact, a certain small proportion of the birds of any extensive collecting may be preferably and very profitably preserved in this way. Specimens in too poor plumage to be worth skinning may be thus utilised; so may the bodies of skinned birds, which, although necessarily defective, retain all the viscera, and also afford osteological material. Alcohol is the liquid usually employed, and, of all the various articles recommended, seems to answer best on the whole. I have used a very weak solution of chloride of zinc with excellent results; it should not be strong enough to show the slightest turbidity. As glass bottles are liable to break when travelling, do not fit corners, and offer practical annoyance about corkage, rectangular metal cans, preferably of copper, with screw-lid opening, are advisable. They are to be set in small, strong, wooden boxes, made to leave a little room for the lid-wrench, muslin bags for doing up separate parcels, parchment for labels, etc. Unoccupied space in the cans should be filled with tow or a similar substance, to prevent the specimens from swashing about. Labelling should be on parchment; the writing should be perfectly dry before immersion; india-ink is the best. Skinned bodies should be numbered to correspond with the dried skin from which taken; otherwise they may not be identifiable. Large birds

thrown in unskinned should have the belly opened, to let in the alcohol freely. Birds may be skinned, after being in alcohol, by simply drying them; they often make fair specimens. Watery moisture that may remain after evaporation of the alcohol may be dried with plaster.

Osteological and other Preparations (Figs. 1-3).—While complete skeletonising of a bird is a special art of some difficulty, and one that does not fall within the scope of this treatise, I may mention two bony preparations very readily made, and capable of rendering ornithology essential service. I refer to the skull, and to the breast-bone with its principal attachments. These parts of the skeleton are, as a rule, so highly characteristic that they afford in most cases invaluable zoological items. To save a skull is of course to sacrifice a skin, to all intents; but you often have mutilated or



FIGS. 1, 2.—Views of sternum and pectoral arch of the ptarmigan, *Lagopus albus*, reduced; after A. Newton. (1) Lateral view, with the bones upside down; (2) viewed from below. *a*, sternum or breast-bone, showing two long slender lateral processes; *b*, ends of sternal ribs; *c*, ends of humerus, or upper-arm bone, near the shoulder-joint; *d*, scapula, or shoulder-blade; *e*, coracoid; *f*, merrythought, or furculum (clavicles).

decayed specimens that are very profitably utilised in this way. The breast-bone (Figs. 1, 2, *a*) excepting when mutilated, is always preservable with the skin, and for choice invoices may form its natural accompaniment. You want to remove along with it the *coracoids* (the stout bones connecting the breast-bone with the shoulders, Figs. 1, 2, *e*), the merrythought (Figs. 1, 2, *f*) intervening between these bones, and the shoulder-blades (Figs. 1, 2, *d*), all without detachment from each other, for these bones collectively constitute the shoulder-girdle, or *scapular arch*. Slice off the large breast muscles close to the bone, and divide their insertions into the wing-bones (*c*); scrape or cut away the muscles that tie the shoulder-blades to the chest; snip off the ribs (Figs. 1, 2, *b*) close to the side of the breast-bone; sever a tough membrane usually found between the prongs of the wish-bone; then, by taking hold of the shoulders (Figs. 1, 2, at *c*), you can lift out the whole affair, dividing some slight connections underneath the bone and behind it. The

following points require attention; the breast-bone often has long slender processes behind and on the sides (the common fowl and the ptarmigan are extreme illustrations of this, as shown in the figures), liable to be cut by mistake for ribs, or to be snapped; the shoulder-blades usually taper to a point, easily broken off; the merrythought is sometimes very delicate or defective. When travelling, it is generally not advisable to make perfect preparations of either skull or sternum; they are best dried with only superfluous flesh removed, and besprinkled with arsenic. The skull, if perfectly cleaned, is particularly liable to lose the anvil-shaped, pronged bones that hinge the jaw, and the freely movable pair that push on the palate from behind. Great care should be exercised respecting the identification of these bones, particularly the sternum, which should invariably bear the number of the spécimen to which it belongs; the label should be tied to the coracoid bone. A skull is more likely to be able to speak for itself, and, besides, is not usually accompanied by a skin; nevertheless, any record tending to facilitate its recognition should be duly entered on the register. There are methods of making elegant bony preparations. You may secure very good results by simply boiling the bones, or, what is perhaps better, macerating them in water till the flesh is completely rotted away, and then bleaching them in the sun. A little potassa or soda hastens the process. With breast-bones, if you can stop the process just when the flesh is completely dissolved, but the tougher ligaments remain, you secure a "natural" preparation, as it is called; if the ligaments go too, the associate parts of a large specimen may be wired together, those of a small one glued. I think it best, with skulls, to clean them entirely of ligament as well as muscle; for the underneath parts are usually those conveying the most desirable information, and they should not be in the slightest degree obscured. Since in such case the anvil-shaped bones, the palatal cylinders already mentioned, and sometimes other portions come apart, the whole are best kept in a suitable box. I prefer to see a skull with the sheath of the beak removed, though in some cases, particularly of hard-billed birds, it may profitably be left on. The completed preparations should be fully labelled by writing on the bone, in preference to an accompanying or attached paper slip, which may be lost. Some object to this, as others do to writing on eggs, that it defaces the specimen; but I confess I see in dry bones no beauty but that of utility.

"In many families of birds, as the ducks (*Anatidæ*), the *trachea* or windpipe of the male affords valuable means of distinguishing between the different natural groups, or even species, chiefly by the form of the bony labyrinth, or *bulla ossea*, situated at or just above the divarication of the bronchial tubes. A little trouble will enable

the collector in all cases to preserve this organ perfectly, as represented in the annexed engraving (Fig. 3). Before proceeding to skin the specimen a narrow-bladed knife should be introduced into its mouth, and by taking hold of the tongue (*A*) by the fingers or forceps, the muscles (*B B*) by which it is attached to the lower jaw should be severed as far as they can be reached, care being of course taken not to puncture the windpipe (*C C*); and later in the operation of skinning, when dividing the body from the neck or head, not to cut into or through it. This done, the windpipe can be easily withdrawn entire and separated from the neck, and then the sternal apparatus being removed as before described, its course must be traced to where, after branching off in a fork (*D*), the bronchial tubes (*E E*) join the lungs. At these latter points it is to be cut off. Then rinsing it in cold water, and leaving it to dry partially, it may, while yet pliant, be either wrapped round the sternum, or coiled up and labelled separately" (Professor Alfred Newton).

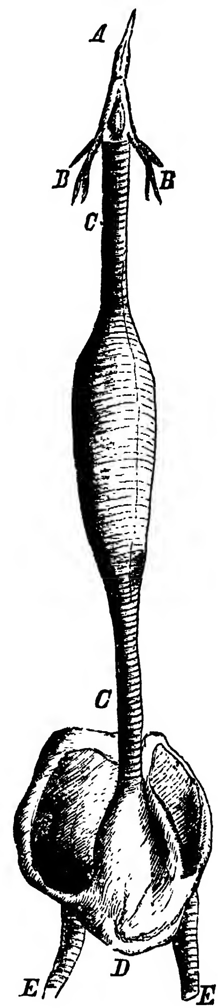


FIG. 3.—Trachea or windpipe of the male red-breasted merganser, *Mergus serrator*, about ½ nat. size, viewed from above (behind); after Newton. *A*, tongue; *B B*, its attachments; *C C*, windpipe, dilated in the middle and swelling below into a bony box, *D*; *E E*, bronchial tubes, going to lungs.

§ 9.—COLLECTION OF NESTS AND EGGS

Ornithology and Oology are twin studies, or rather one includes the other. A collection of nests and eggs is indispensable for any thorough study of birds; and many persons find peculiar pleasure in forming one. Some, however, shrink from robbing birds' nests as something particularly cruel — a sentiment springing, no doubt, from the sympathy and deference that the tender office of maternity inspires. But with all proper respect for the humane emotion, it may be said simply, that birds'-nesting is not nearly so cruel as bird-shooting. What I said in a former section, in endeavouring to guide search for birds, applies in substance to hunting for their nests; the essential difference is, that the latter are of

course stationary objects, and consequently more liable to be overlooked, other things being equal, than birds themselves. Most birds nest on trees or bushes; many on the ground and on rocks; others in hollows. Some build elegant, elaborate structures, endlessly varied in details of form and material; others make no nest whatever. Egging is chiefly practicable in May and during the summer; but some species, particularly birds of prey, begin to lay late in winter or early in spring, so there is really a long period for search. Particular nests, of course, like the birds that build them, can only be found through ornithological knowledge; but general search is usually rewarded with a varied assortment. The best clue to a hidden nest is the action of the parents; patient watchfulness is commonly successful in tracing the bird's home. As the science of oology has not progressed to the point of determining from the nests and eggs to what bird they belong, in even a majority of cases, the utmost care in authentication is indispensable. To be worth anything, not to be worse than worthless in fact, an egg must be identified beyond question; must be not only unsuspected, but above suspicion. A shade of suspicion is often attached to dealers' eggs; not necessarily implying bad faith or even negligence on the dealer's part, but from the nature of the case. It is often extremely difficult to make an unquestionable determination, as, for instance, when numbers of birds of similar habits are breeding close together; or even impossible, as in case the parent eludes observation. Sometimes the most acute observer may be mistaken, circumstances appearing to prove a parentage when such is not the fact. It is in general advisable to secure the parent with the eggs: if shot or snared on the nest, the identification is unquestionable. If you do not yourself know the species, it then becomes necessary to secure the specimen, and retain it with the eggs. It is not required to make a perfect preparation; the head, or better, the head and a wing, will answer the purpose. When egging in downright earnest, a pair of climbing irons, a coil of ⅜ inch rope, and a tin collecting box filled with cotton, become indispensable; these are the only field implements required in addition to those already specified.

Preparing Eggs.—For blowing eggs, a set of special tools is needed. These are egg-drills,—steel implements with a sharp-pointed conical head of rasping surface, and a slender shaft; several such, of different sizes, are needed; also, blow-pipes of different sizes, a delicate thin pair of scissors, light spring forceps, some little hooks, and a small syringe. They are inexpensive, and may be had of any dealer in naturalists' supplies (see Figs. 4-7). Eggs should never be blown in the old way of making a hole at each end; nor are two holes anywhere usually required. Opening should be effected on one side, preferably that showing least conspicuous or

characteristic markings. If two are made, they should be rather near together; on the same side at any rate. But one is generally sufficient, as the fluid contents can escape around the blow-pipe. Holding the egg gently but steadily in the fingers,[1] apply the point of the drill perpendicularly to the surface, unless it be preferred to prick with a needle first. A twirling motion of the instrument gradually enlarges the opening by filing away the shell, and so bores a smooth-edged circular hole. This should be no larger than is required to insert the blow-pipe loosely, with room for the contents to escape around it. Nor is it always necessary to insert the pipe; a fine stream of water may be easily injected by holding the instrument close to the egg, but not quite touching. The blowing should be continuous and equable, rather than forcible; a strong puff easily bursts a delicate egg. Be sure that all the contents are removed; then rinse the interior thoroughly with clean water, either by taking a mouthful and sending it through a blow-pipe, or with the syringe. Blowing eggs is a rather fatiguing process;

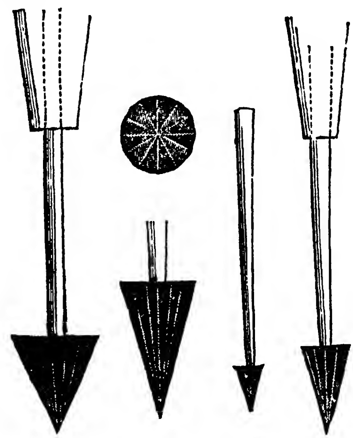


FIG. 4.—Egg-drills, different sizes, nat. size; after Newton.

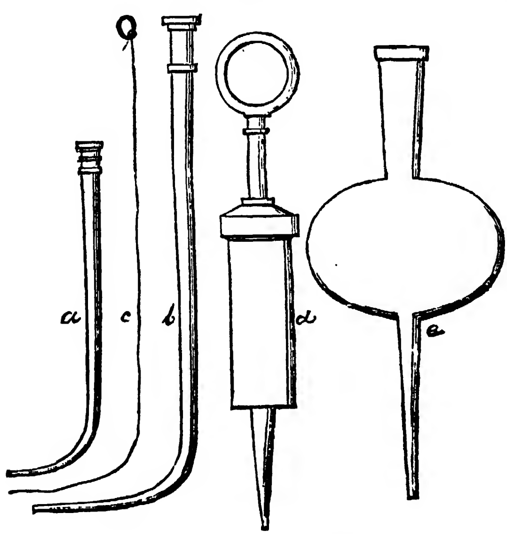


FIG. 5.—Instruments for blowing eggs; after Newton. *a*, *b*, blow-pipes, ½ nat. size; *c*, wire for cleansing them; *d*, syringe, ½ nat. size (the ring of the handle must be large enough to insert the thumb); *e*, bulbous insufflator, for sucking eggs.

[1] The usual method of emptying eggs through one small hole is doubtless

the cheek-muscles soon tire, and the operator becomes "blown" himself before long. The operation had better be done over a basin of water, both to receive the contents, and to catch the egg if it slip from the fingers. The membrane lining the shell

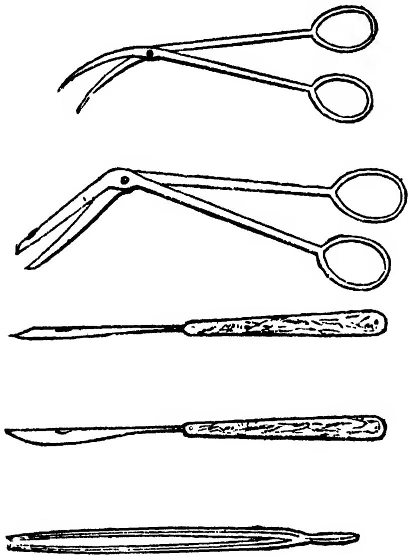


FIG. 6.—Scissors, knives, and forceps, ½ nat. size; after Newton.

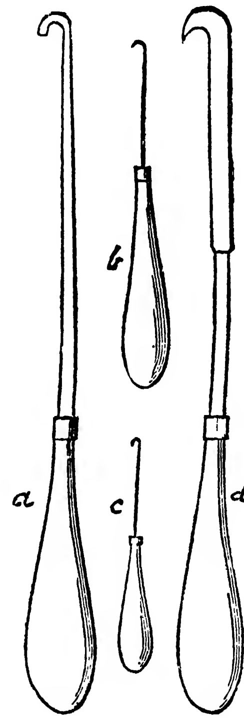


FIG. 7.—Hooks for extracting embryos, nat. size; after Newton. *a, b, c*, plain hooks; *d*, bill-hook, having cutting edge along the concavity.

should be removed if possible. It may be seized by the edge around the hole, with the forceps, and drawn out, or picked out with a bent pin. But this is scarcely to be accomplished in the case of fresh eggs, when the membrane may be simply pared smoothly around the edge of the hole. Eggs that have been incubated of course offer difficulty, in proportion to the size of the embryo. The

supposed to be a very modern trick; but it dates back at least to 1828, when M. Danger proposed "a new method of preparing and preserving eggs for the cabinet," which is practically the one now followed, though he used a three-edged needle to prick the hole, instead of our modern drill, and did not appear to know some of our ways of managing the embryo. I make this reference to his article to call attention to one of the tools he recommends, which I think would prove useful, as being better than the fingers for holding an egg during drilling and blowing. The simple instrument will be understood from a glance at the figure given in the *Nuttall Bulletin*, iii. 1878, p. 191. The oval rings are covered with a light fabric, as mosquito-netting or muslin, and do not touch the egg, which is held lightly but securely in the netting. The cost would be trifling, and danger might be avoided by Danger's method.

hole may be drilled, as before, but it must be larger; and as the drill is apt to split a shell after it has bored beyond a certain size of hole, it is often well to prick, with a fine needle, a circular series of minute holes almost touching, and then remove the enclosed circle of shell. This must be very carefully done, or the needle will indent or crack the shell, which, it must be remembered, grows more brittle towards the time of hatching. Well-formed embryos cannot be got bodily through any hole that can be made in an egg; they must be extracted piecemeal. They may be cut to pieces with the slender scissors introduced through the hole, and the fragments be picked out with the forceps, hooked out, or blown out. No embryo should be forced through a hole too small; there is every probability that the shell will burst at the critical moment. Addled eggs, the contents of which are thickened or hardened, offer some difficulty, to overcome which persistent syringing and repeated rinsing are required; or it may be necessary to fill them with water, and set them away for such length of time that the contents dissolve by maceration; carbonate of soda is said to hasten the solution; the process may be repeated as often as may be necessary. In no event must any of the animal contents be suffered to remain in the shell. When emptied and rinsed, eggs should be gently wiped dry, and set hole downward on blotting-paper to drain.[1] Broken eggs may be neatly mended, sometimes with a film of collodion, or a bit of tissue paper and paste, or the edges may be simply stuck together with any adhesive substance. Even when fragmentary a rare egg is worth preserving. Eggs should ordinarily be left empty; indeed, the only case in which any filling is admissible is that of a defective

[1] *Reinforcing the Eggshell before Blowing.*—Fig. 8 "shows a piece of paper, a number of which, when gummed on to an egg, one over the other, *and left to dry,* strengthen the shell in such a manner that the instruments above described can be introduced through the aperture in the middle and worked to the best advantage, and thus a fully formed embryo may be cut up, and the pieces extracted, through a very moderately sized hole, the number of thicknesses required depends, of course, greatly upon the size of the egg, the length of time it has been incubated, and the stoutness of the shell and the paper. Five or six is the least number that it is safe to use. Each piece should be left to dry before the next is gummed on. The slits in the margin cause them to set pretty smoothly, which will be found very desirable; the aperture in the middle of each may be cut out first, or the whole series of layers may be drilled through when the hole is made in the egg. For convenience' sake, the papers may be prepared already gummed, and moistened when put on (in the same way that adhesive postage labels are used). Doubtless, patches of linen or cotton cloth would answer equally well. When the operation is over, a slight application of water (especially if warm) through the syringe will loosen them so that they can be easily removed, and they can be separated from one another, and dried to serve another time. The size represented in the sketch is that suitable for an egg of moderate dimension, such as that of a common fowl. The most effectual way of adopting

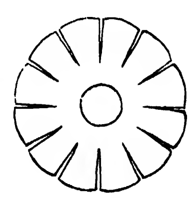


FIG. 8.—Nat. size.

specimen to which some slight solidity can be imparted with cotton. It is unnecessary even to close up the hole. It is best, on all accounts, to keep eggs in *sets*, a set being the natural clutch, or whatever less number was taken from a nest. The most scrupulous attention must be paid to accurate, complete, and permanent labelling. So important is this, that the undeniable defacing of a specimen, by writing on it, is no offset to the advantages accruing from such fixity of record. It is practically impossible to attach a label, as is done with a birdskin, and a loose label is always in danger of being lost or displaced. Write on the shell, then, as many items as possible; if done neatly, on the side in which the hole was bored, at least one good "show side" remains. An egg should always bear the same number as the parent, in the collector's record. In a general collection, where separate ornithological and oological registers are kept, identification of egg with parent is nevertheless readily secured, by making one the numerator the other the denominator of a fraction, to be simply inverted in its respective application. Thus, bird No. 456 and egg No. 123 are identified by making the former $\frac{456}{123}$, the latter $\frac{123}{456}$. All the eggs of a clutch should have the same number. If the shell be large enough, the name of the species should be written on it; if too small, it should be accompanied by a label, and may have the name indicated by a number referring to a certain catalogue. According to my "Check List," for example, No. 4 would indicate *Turdus iliacus*, the common redwing. The date of collection is a highly desirable item; it may be abbreviated thus: 3/6/82 means 3d June 1882. It is well to have the egg authenticated by the collector's initials at least. Since sets of eggs may be broken up for distribution to other cabinets, yet permanent indication of the size of the clutch be wanted, it is well to have some method. A good one is to write the number of the clutch on each egg composing it, giving each egg of the set, moreover, its individual number. Supposing, for example, the clutch No. $\frac{123}{456}$ contained five eggs; one of of them would be $\frac{123}{456}$ /5/1: the next $\frac{123}{456}$ /5/2, and so on. But it should be remembered that all such arbitrary memoranda must be systematic, and be accompanied by a key. Eggs may be kept in cabinets of shallow drawers in little pasteboard trays, each holding a set, and containing a paper label on which various items that

this method of emptying eggs is by using *very many layers of thin paper and plenty of thick gum*, but this is, of course, the most tedious. Nevertheless, it is quite worth the trouble in the case of really rare specimens, and they will be none the worse for operating upon from the delay of a few days caused by waiting for the gum to dry and harden. The naturalist to whom this method first occurred has found it answer remarkably well in every case in which it has been used, from the egg of an eagle to that of a humming-bird, and among English oologists it has been generally adopted" (A. Newton, in *Smithsonian Misc. Coll.*, p. 139, 1860).

cannot be traced on the shell are written in full. Such trays should all be of the same depth,—half an inch is a convenient depth for general purposes; and of assorted sizes, say from one inch by one and one-half inches up to three by six inches; it is convenient to have the dimensions regularly graduated by a constant factor of, say half an inch, so that the little boxes may be set side by side, either lengthwise or crosswise, without interference. Eggs may also be kept safely, advantageously, and with attractive effect, in the nests themselves, in which a fluff of cotton may be placed to steady them. When not too bulky, too loosely constructed, or of material unsuitable for preservation, nests should always be collected.[1] Those that are very closely attached to twigs should not be torn off. Nests threatening to come to pieces, or too frail to be handled without injury, may be secured by sewing through and through with

[1] "A Plea for the Study of Nests," made by Mr. Ernest Ingersoll in his excellent *Birds'-Nesting*, suits me so well that I will transcribe it. "Whether or not it is worth while to collect nests—for there are many persons who never do so—is, it seems to me, only a question of room in the cabinet. As a scientific study there is far more advantage to be obtained from a series of nests than from a series of eggs. The nest is something with which the will and energies of the bird are concerned. It expresses the character of the workman; is to a certain extent an index of its rank among birds,—for in general those of the highest organisation are the best architects,—and give us a glimpse of the bird's mind and power to understand and adapt itself to changed conditions of life. Over the shape and ornamentation of an egg the bird has no control, being no more able to govern the matter than it can the growth of its beak. There is as much difference to me, in the interest inspired, between the nest and the egg of a bird, as between its brain and its skull,—using the word brain to mean the seat of intellect. The nest is always more or less the result of conscious planning and intelligent work, even though it does follow a hereditary habit in its style; while the egg is an automatic production varying, if at all, only as the whole organisation of the bird undergoes change. Don't neglect the nests then. In them more than anywhere else lies the key to the mind and thoughts of a bird,—the spirit which inhabits that beautiful frame and bubbles out of that golden mouth. And is it not this inner life,—this human significance in bird nature,—this *soul* of ornithology, that we are all aiming to discover? Nests are beautiful, too. What can surpass the delicacy of the humming-bird's home glued to the surface of a mossy branch or nestling in the warped point of a pendent leaf; the vireo's silken hammock; the oriole's gracefully swaying purse; the blackbird's model basket in the flags; the snug little caves of the marsh wrens; the hermitage-huts of the shy wagtails and ground warblers, the stout fortresses of the sociable swallows! Moreover, there is much that is highly interesting which remains to be learned about nests, and which can only be known by paying close attention to these artistic masterpieces of animal art. We want to know by what sort of skill the many nests are woven together that we find it so hard even to disentangle; we want to know how long they are in being built; whether there is any particular choice in respect to location; whether it be a rule, as is supposed, that the female bird is the architect, to the exclusion of her mate's efforts further than his supplying a part of the materials. Many such points remain to be cleared up. Then there is the question of variation, and its extent in the architect of the same species in different quarters of its ranging area. How far is this carried, and how many varieties can be recorded from a single district, where the same list of materials is open to all the birds equally? Variation shows individual opinion or taste among the builders as to the suitability of this or that sort of timber or furniture for their dwellings, and observations upon it thus increase our acquaintance with the scope of ideas and habits characteristic of each species of bird."

fine thread: indeed, this is an advisable precaution in most cases. Packing eggs for transportation requires much care, but the precautions to be taken are obvious. I will only remark that there is no safer way than to leave them in their own nests, each wrapped in cotton, with which the whole cavity is to be lightly filled; the nests themselves being packed close enough to be perfectly steady.

§ 10.—CARE OF A COLLECTION

Well-preserved Specimens will last "for ever and a day," so far as natural decay is concerned. I have handled birds in good state, shot back in the twenties, and have no doubt that some eighteenth-century preparations are still extant. The precautions against defilement, mutilation, or other mechanical injury, are self-evident, and may be dismissed with the remark, that white plumages, especially if at all greasy, require the most care to guard against soiling. We have, however, to fight for our possessions against a host of enemies, individually despicable but collectively formidable,—foes so determined that untiring vigilance is required to ward off their attacks even temporarily, whilst in the end they prove invincible. It may be said that to be eaten up by insects is the natural end of all bird-skins not sooner destroyed.

Insect Pests (Figs. 9, 10, 11, 12) with which we have to contend belong principally to the two families *Tineidæ* and *Dermestidæ*—the former are moths, the latter beetles. The moths are of species identical with, and allied to, the common clothes-moth, *Tinea flavifrontella*, the carpet moth, *T. tapetzella*, etc.,—small species observed flying about our apartments and museums, in May and during the summer. The beetles are several rather small thick-set species, principally of the genera *Dermestes* and *Anthrenus*. I am able to figure species of these genera, with their larval stages, and of two other genera, *Ptinus* and *Sitodrepa*, through the attentions of Professor C. V. Riley, the eminent entomologist. The larvæ ("caterpillars" of the moths, and "grubs" of the beetles) appear to be the chief agents of the destruction. The presence of the mature insects is usually readily detected; on disturbing an infested suite of specimens the moths flutter about, and the beetles crawl as fast as they can into shelter, or simulate death. The insidious larvæ, however, are not so easily observed, burrowing as they do among the feathers, or in the interior of a skin; whilst the minute eggs are commonly altogether overlooked. But these insects are not long at work without leaving their unmistakable traces. Shreds of feathers float off when a specimen is handled, or fly out on flip-

ping the skin with the fingers, and in bad cases even whole bundles of plumes come away at a touch. Sometimes, leaving the plumage intact, insects eat away the horny covering of the bill and feet, making an irreparable mutilation. It would appear that when the pests effect lodgment in any one skin, they usually finish it before attacking another, unless they are in great force. We may con-

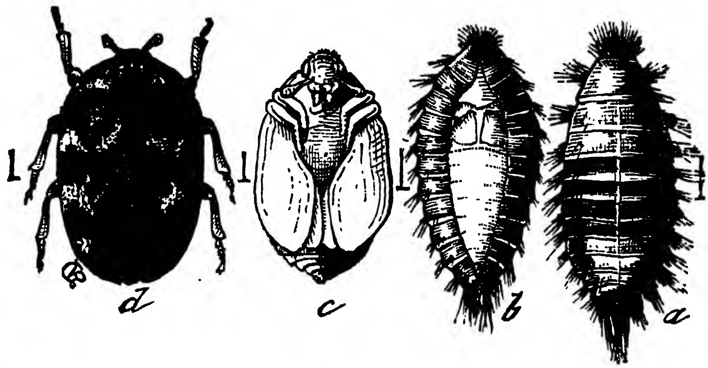
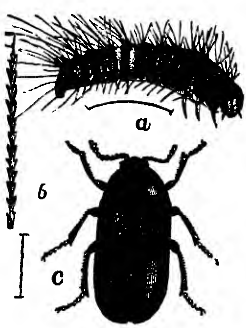
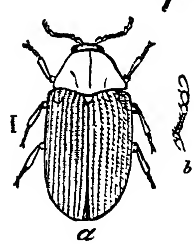


FIG. 9.—*Anthrenus scrophulariæ*, enlarged; the short line shows nat. size. *a*, *b*, larvæ; *c*, pupa; *d*, imago.





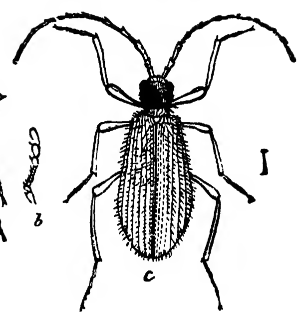


FIG. 10.—*Dermestes lardarius*, enlarged. *a*, larva; *b*, an enlarged hair; *c*, imago.

FIG. 11.—*Sitodrepa panicea*, enlarged. *a*, imago; *b*, its antenna, more enlarged.

FIG. 12.—*Ptinus brunneus*.

sequently, by prompt removal of an infested specimen, save further depredations; nevertheless, the rest become suspicious, and the whole drawer or box should be quarantined, if not submitted to any of the processes described beyond. Our lines of defence are several. We may mechanically oppose entrance of the enemy; we may meet him with abhorrent odours that drive him off, sicken or kill him, and finally we may cook him to death. I will notice these methods successively, taking occasion to describe a cabinet under the first head.

Cases for Storage or Transportation should be rather small, for several reasons. They are easier to handle and pack. There are fewer birds pressing each other. Particular specimens are more readily reached. Insects must effect just so many more separate entrances to infest the whole. Small lids are more readily fitted tight. For the ordinary run of small birds I should not desire a box over 18 × 18 × 18 inches, and should prefer a smaller one; for large birds, a box just long enough for the biggest specimen, and of other proportions to correspond, is most eligible. Whatever the dimensions, a proper box presupposes perfect jointing; but if any suspicion be entertained on this score, stout paper should be pasted along all the edges, both inside and out. We have practically to do with the lid only. If the lot is likely to remain long untouched, the cover may be screwed very close and the crack pasted like the others. Under other and usual circumstances the lid may be provided with a metal boss fitting a groove lined with india-rubber or filled with wax. An excellent case may be made of tin with the lid secured in this manner, and further fortified with a wooden casing. Birdskins entirely free from insects or their eggs, encased in some such secure manner, will remain intact indefinitely; but there is misery in store if any bugs or nits be put away with them.

Cabinets.—As a matter of fact, most collections are kept readily accessible for examination, display, or other immediate use, and this precludes any disposition of them in hermetical cases. The most we can do is to secure tight fitting of movable woodwork. The cabinet is most eligible for private collections. This is, in effect, simply a bureau, or chest of drawers, protected with folding doors, or a front that may be detached, either of plain wood or sashing for panes of glass. It is astonishing how many birdskins of average size can be accommodated in a cabinet that makes no inconvenient piece of furniture for an ordinary room. A cabinet may of course be of any desired size, shape, and style. In general it will be better to put money into excellence of fitting rather than elegance of finish; the handsomest front does not compensate for a crack in the back or for a drawer that hitches. There should not be the slightest flaw in the exterior, and doors should fit so tightly that a puff of air may be felt on closing them. The greatest desideratum of the interior work, next after close fitting yet smooth running of the drawers, is economy of space. This is secured by making the drawers as thin as is consistent with stability; by having them slide by a boss at each end fitting a groove in the side wall, instead *of resting on horizontal partitions;* and by hinged countersunk *handles instead of knobs. I do not recommend, except for a suite* of the smallest birds, a multiplicity of shallow drawers, accommodating each one layer of specimens; it is better to have fewer deeper

drawers, into which light shallow movable trays are fitted. These trays never need be of stuff over one-eighth or one-fourth of an inch thick, and may have bottoms of stiff pasteboard glued or tacked on. They may vary from one-half inch to two inches in depth, but this dimension should always be some factor of the depth of the drawer, so that a certain number of trays may exactly fill it. They should be just as long as one transverse dimension of the drawer, and rather narrow, so that two or more are set side by side. Finally, though they may be of different depths, they should be of the same length and breadth, so as to be interchangeable. They may simply rest on top of each other, or slide on separate projections inside the drawer. Such trays are extremely handy for holding particular sets of specimens, to be carried to the study table without disturbing the rest of the collection.

If a collection be so extensive that any particular specimen may not be readily hunted up, it will be found convenient to have the drawers themselves labelled with the name of the group within. A collection should always be methodically arranged—preferably according to some approved or supposed natural classification of birds; this is also the readiest mode, since, with some conspicuous exceptions, birds of the same natural group are approximately of the same *size*. If I were desired to suggest proportions for a private cabinet of most general eligibility, I should say four feet high, by three feet wide, by two feet deep, in the clear; this makes a portly yet not unwieldy-looking object. It is wide enough for folding-doors, to be secured by bolts at top and bottom, and lock; not so high that the top drawer is not readily inspected; and of proportionate depth. Such a case will take seven drawers six inches deep either of the full width or in two series with a median partition; these drawers will hold anything up to an eagle or crane. A part of them at least should have a full complement of such trays as I have described,—say three or four tiers of the shallower trays, three trays to a tier, each about two feet long by about a foot wide; and one or two tiers of deeper trays.

To Destroy Insects.—In our present case prevention is not the best remedy, simply because it is not always practicable; in spite of all mechanical precautions the insects will get in. We have, therefore, to see what will destroy them, or at least stop their ravages. It is a general rule that any pungent aromatic odour is obnoxious to them, and that any very light powdery substance restrains their movements by getting into the joints and breathing pores. Both these qualities are secured in the ordinary insect powder, to be had of any leading druggist. It should be lavishly strewn on and among the skins, and laid in the corners of the drawers and trays. Thus employed it proves highly effective, and

is on the whole the most eligible substance to use when a collection is constantly handled. Camphor is a valuable agent. Small fragments may be strewn about the drawers, or a lump pinned in mosquito netting in a corner. Benzine is also very useful. A small saucerful may be kept evaporating, or the liquid may be sprinkled—even poured—directly over the skins; it is very volatile and leaves little or no stain. It is, however, obviously ineligible when a collection is in constant use. My friend Mr. Allen informs me he has used sulphide of carbon with great success. The objection to this agent is, that it is a stinking poison; should be used in the open air, to escape the ineffably disgusting and deleterious odours, and its employment is properly restricted to cases for storage. When the bill or feet show they are attacked, further depredation may be prevented by pencilling with a strong solution of corrosive sublimate; a weaker solution, one that leaves no white film, on drying, on a black feather, may even be brushed over the whole plumage. Mr. Ridgway tells me that oil of bitter almonds is equally efficacious. But remember that these poisons must be used with care. Specimens may be buried in coarse refuse tobacco leaves. One or another of these lines of defence will commonly prove successful in destroying or driving off mature insects, and even in stopping the ravages of the larvæ; but I doubt that any such means will kill the eggs. With these we must deal otherwise; and their destruction no less than that of their parents is assured, if we subject them to a high temperature. Baking birdskins is really the only process that can make us feel perfectly safe. Infected specimens, along with suspected ones, should be subjected to a dry heat, from 212° F. up to any degree short of singeing the plumage. This is readily done by putting the birds in a wooden tray in any oven—they must however be watched, unless you have special contrivances for regulating the temperature. How long a time is required is probably not ascertained with precision; it will be well to bake for several hours. When the beetles and larvæ are found completely parched, it may be confidently believed that the unseen eggs are out of the hatching way for ever.

Arsenic helps to keep out the bugs, besides preventing decay—a fact that should never be forgotten, and that should give sharper edge to my advice respecting lavish use of the substance at the outset. If it be true, as some state, that bugs can eat arsenic without dying, it is also true that they do not relish it; and in entering a case of skins they will burrow by preference in those holding the least of it. This fact is continually exhibited in large collections, where if two birds be side by side, one being duly arsenicised and the other not so, one will be taken and the other left. It is also a fact in the natural history of these our pests, that they are fond of peace and

quiet,—they do not like to be disturbed at their meals. So they rarely effect permanent lodgment in a collection that is constantly handled, though the doors stand open for hours daily. As a consequence, the degree of our diligence in *studying* birdskins is likely to become the measure of our success in preserving them. I once read a work, by an eminent divine, on the *Moral Uses of Dark Things*, under which head the author included every dark thing from earthquakes to mosquitoes. If there be a moral use in the "dark thing" that museum pests certainly are to us, we have it here. The very bugs urge on our work.

FIG. 13.—ALEXANDER WILSON'S SCHOOL-HOUSE, NEAR GRAY'S FERRY, PHILADELPHIA, U.S.A. From a drawing by M. S. Weaver, Oct. 22, 1841, received by Elliot Coues, February 1879, from Malvina Lawson, daughter of Alexander Lawson, Wilson's engraver. See article in the *Penn Monthly*, June 1879, p. 443. The drawing was first engraved on wood, and published, by Thomas Meehan, in the *Gardener's Monthly*, August 1880, p. 248. The present impression is from an electrotype of that woodcut. The size of the original is 5·10×3·95 inches. This reminder of early days of "Field Ornithology" in America may be further attested by the signature of

PART II

GENERAL ORNITHOLOGY

AN OUTLINE OF THE

STRUCTURE AND CLASSIFICATION OF BIRDS

GENERAL ORNITHOLOGY

§ 1.—DEFINITION OF BIRDS

GENERAL Ornithology, like Field Ornithology, is a subject with which the student must have some acquaintance, if he would hope to derive either pleasure or profit from the Birds of Great Britain. For any intelligent understanding of this subject, he must become reasonably familiar with the technical terms used in describing and classifying birds, and learn at least enough of the structure of these creatures to appreciate the characters upon which all description and classification is based. Extensive and varied and accurate as may be his random perception of objects of natural history, his knowledge is not scientific, but only empirical, until reflection comes to aid observation, and conceptions of the significance of what he knows are formed by logical processes in the mind. For

Science (Lat. *scire*, to know) is knowledge set in order; knowledge disposed after the rational method that best shows, or tends to show best, the true relations of observed facts. Sound scientific facts are the natural basis of all philosophic truth, and the safest stepping-stones to religious faith,—to that wisdom which comes only of knowing the relation which material entities bear to spiritual realities. The orderly knowledge of any particular class of facts—the methodical disposition of observations upon any particular set of objects—constitutes a Special Science. Thus

Ornithology (Gr. ὄρνιθος, *ornithos*, of a bird; λόγος, *logos*, a discourse) is the Science of Birds. Ornithology consists in the rational arrangement and exposition of all that is known of birds, and the logical inference of much that is not known. Ornithology treats of the physical structure, physiological processes, and mental attributes of birds; of their habits and manners; of their geo-

graphical distribution and geological succession; of their probable ancestry; of their every relation to one another and to all other animals, including man,—in short, of their significance in Nature. The first business of Ornithology is to define its ground—to answer the question

What is a Bird?—There is every reason to believe that a Bird *is a greatly* modified Reptile, being the offspring by direct descent *of some reptilian progenitor;* and there is no reason to suppose that any bird ever had any other origin than by due process of *hatching* out of an egg laid by its mother after fecundation by its father,—just what we believe to have been the invariable method during the period of the world known to human history. There is no reason to believe that any bird was ever originally created and endowed with the characters it now possesses; but that every bird now living is the naturally modified lineal descendant of parents that were less and less like itself, and more and more like certain reptiles, the further removed they were in the line of avian ancestry from such birds as are now living. This is the Darwinian logic of observed facts, upon which the modern Theory of Evolution is based, in opposition to the tradition of the special creation of every species of animal; which latter has no scientific basis whatever, and is consequently accepted as true by few thoughtful persons who are capable of forming independent judgments. Accordingly,

Birds and Reptiles—even those of the present geologic epoch —share so many and so important structural characters, that the chiefs of science of our day are wont to unite the two classes, *Aves* and *Reptilia,* in one primary group of the *Vertebrata,* or animals with a backbone. This group is called *Sauropsida,* or reptiliforms; it is contrasted, on the one hand, with *Ichthyopsida,* or fish-like vertebrates, including Batrachians as well as Fishes; and, on the other, with *Mammalia,* the province of the Vertebrata which includes Man and all other animals that suckle their young. We find that

The Sauropsida (Gr. σαῦρος, *sauros,* a reptile; ὄψις, *opsis,* appearance), or lizard-like Vertebrates, agree with one another, and differ from other animals, in the following important combination of characters, substantially as laid down by Professor Huxley,—some of the characters being shared by the *Ichthyopsida,* and some by the *Mammalia,* but the sum of the characters being distinctive of *Sauropsida:* they are all oviparous (laying eggs hatched outside the body of the parent), or ovoviviparous (laying eggs hatched inside the body of the parent), being never viviparous (bringing forth alive young nourished before birth by the blood of the mother). The embryo develops those fœtal organs called *amnion* and *allantois,* and is

nourished before hatching by the great quantity of food-yolk in the egg. There are no mammary glands to furnish the young with milk after birth. The generative, urinary, and digestive organs come together behind in a common receptacle, the *cloaca*, or sewer, and their products are discharged by a single orifice. The kidneys of the early embryo, called *Wolffian bodies*, are soon replaced functionally by permanent kidneys, and structurally by the *testes* of the male and the *ovaries* of the female. The cavity of the *abdomen*, or belly, is not separated from that of the *thorax*, or chest, by a complete muscular partition, or *diaphragm*. The great lateral hemispheres of the brain are not connected by a transverse commissure, or *corpus callosum*. Air is always breathed by true lungs, never by gills. The blood, which may be cold or hot, has red oval nucleated corpuscles; the heart has either three or four separate chambers,—the latter in birds, in which the circulation of the hot blood is completely double, *i.e.* in the lungs and one side of the heart, in the body at large and the other side of the heart. The *aortic* arches are several; or if but one, as in birds, it is the right, not the left as in mammals. The *centra*, or bodies, of the vertebræ are ossified, but have no terminal *epiphyses*. The skull hinges upon the backbone by a single median protuberance, or *condyle*, and the bone (*basioccipital*) bearing this condyle is completely ossified. The lower jaw consists of several separate pieces, the articular one of which hinges upon a movable *quadrate* bone; and there are other peculiarities in the formation of the skull. The ankle-joint is situated, not, as in Mammals, between the *tarsal* bones and those of the leg, but between two rows of tarsal bones. The skin is usually covered with outgrowths, in the form of scales or feathers. Different as are any living members of the class of Birds from any known Reptiles, the characters of the two groups converge in geologic history so closely, that the presence of *feathers* in the former class, and their absence from the latter, is one of the most positive differences we have found. The oldest known birds are from the Jurassic rocks of Europe, and the Cretaceous beds of North America. These birds had teeth, and various other strong peculiarities of structure, which no living members of the class have retained.

AVES, or the Class of Birds, may be distinguished from other *Sauropsida*, for all that is known to the contrary, by the following sum of characters: The body is covered with feathers, a kind of skin-outgrowth no other animals possess. The blood is hot; the circulation is completely double; the heart is perfectly four-chambered; there is but one (the right) aortic arch, and only one pulmonary artery springs from the heart; the aortic and the pulmonary artery have each three semilunar valves. The lungs are fixed and moulded to the cavity of the chest, and some of the air-

passages run through them to admit air to other parts of the body, as under the skin and in various bones. Reproduction is oviparous; the eggs are very large, in consequence of their copious yolk and white; have a hard chalky shell, and are hatched outside the body of the parent. There are always four limbs, of which the fore or pectoral pair are strongly distinguished from the hind or pelvic pair by being modified into *wings*, fitted for flying, if at all, by means of feathers—not of skin as in the cases of such mammals, reptiles, and fishes as can fly. The terminal part of the limb is compressed and reduced, bearing never more than three digits, only two of which ever have claws, and no claws being the rule. There are not more than two separate *carpals*, or wrist-bones, in adult recent birds (with very rare exceptions); nor any distinct inter-clavicular bone. The clavicles are complete (with rare exceptions), and coalesce to form a "wish-bone" or "merrythought." The *sternum*, or breast-bone, is large, usually *carinate*, or keeled, and the ribs are attached to its sides only; it is developed from two to five or more centres of ossification. The *sacral* vertebræ proper have no expanded ribs abutting against the *ilia;* the ilia, or haunch-bones, are greatly prolonged forward; the socket for the head of the *femur*, or thigh-bone, is a ring, not a cup; the *ischia* and *pubes* are prolonged backward in parallel directions, and neither of these bones ever unites with its fellow in a ventral symphysis (except in *Struthio* and *Rhea*). The *fibula*, or outer bone of the leg, is incomplete below, taking no part in the ankle-joint. The *astragalus*, or upper bone of the tarsus, unites with the *tibia*, or inner bone of the leg, leaving the ankle-joint between itself and other tarsal bones, the lower of which latter similarly unites with the bones of the instep, or *metatarsus*. There are never more than four metatarsal bones, and the same number of digits; the first or inner metatarsal bone is usually free, and incomplete above; the other three anchylose (fuse) together, and with distal tarsal bones, as already said, to form a compound tarso-metatarsus. Recent birds, at any rate, have a certain saddle-shape of the ends of the bodies of some vertebræ. Such birds have also no teeth and no fleshy lips; the jaws are covered with horny or leathery integument, as the feet are also, when not feathered.

The Position of the Class Aves among other Vertebrates is definite. Birds come in the scale of development next below the Class *Mammalia*, and no close links between Birds and Mammals are known; the most bird-like known mammal, the duck-billed platypus of Australia (*Ornithorhynchus paradoxus*), being several steps beyond any known bird. Birds are the higher one of the two classes of *Sauropsida*—the lower class, *Reptilia*, connecting with the Batrachians (frogs, toads, newts, etc.), and so with the Fishes, *Ichthyopsida*. In

this Vertebrate series, Birds constitute what is called a *highly specialised* group; that is to say, a very particular offshoot, or, more literally, a side-issue, of the Vertebrate genealogical tree, which in the present geological era has become developed into very numerous (about 10,000) species, closely agreeing with one another in the peculiar sum of their physical character. In comparison with other classes of Vertebrates, all birds are much alike; there is a less degree of difference among them than that found among the members of any of the other classes of Vertebrates; their likeness to each other being strong, and their kind of difference from any other Vertebrates being peculiar, makes them the highly specialised class they are recognised to be. The structural difference between a humming-bird and an ostrich, for example, is not greater in degree than that subsisting between the members of some of the orders of Reptiles; whence some hold, with reason, that Birds should not form a class *Aves*, but an order, or at most a sub-class, of *Sauropsida*, and so be compared not with a class *Reptilia* collectively, but with other sauropsidan orders, such as *Chelonia* (turtles), *Sauria* (lizards), *Ophidia* (serpents), etc. The practical convenience of starting with a "class" *Aves*, however, is so great, that such classificatory value will probably long continue to be ascribed, as heretofore, to Birds collectively. I have spoken of Birds as a particular side-issue or lateral branch of the Vertebrate "tree of life"; hence it is not to be supposed that they are in the direct line of genealogical descent. Though they stand as a group next below Mammals in the scale of evolution, it does not follow that Mammals were developed from any such creature as a Bird has come to be, any more than that Birds have been evolved from any such Reptiles as those of the present day. It is one of the popular misunderstandings of the Theory of Evolution, to imagine that all the lower forms of animals are in the genetic line of development of the higher forms; that man, for example, was once a gorilla or a chimpanzee—actually such an ape. The theory simply requires all forms of life to be developed from *some* antecedent form, presumably, and in most cases certainly, lower in the scale of organisation. Thus man and the gorilla are both descendants of some common progenitor, more or less unlike either of these existing creatures. All mammals are similarly the modified descendants of some more primitive stock, from which stock sprang also all *Sauropsida*, mediately or immediately; therefore a Mammal is not a modified Bird, though higher in the scale; and, though a Bird is a modified Reptile, it is not a modification of any such snake or lizard as now exists. The most bird-like reptiles known are not the Pterodactyls, or Flying Reptiles (*Pterosauria*), as might be supposed; but belong to that remarkable order, the *Ornithoscelida*, comprising the Dinosaurians, which "present a large series of

modifications intermediate in structure between existing *Reptilia* and *Aves*," and are therefore inferentially in the direct ancestral line of modern Birds.

Geologic Succession of Birds.—Birds have been traced back in geologic time to Cretaceous and Jurassic epochs of the Mesozoic or Mid-Life period of the world's history. The earliest *ornithichnites*,—the fossils so called because supposed to indicate the presence of Birds by their footprints, were discovered about the year 1835 in the Triassic formation in Connecticut. But the creatures which made these tracks are now reasonably believed to have been all Dinosaurian reptiles. The oldest *ornitholite*, or fossil certainly known to be that of a true Bird, is the famous *Archæopteryx*, found by Andreas Wagner in 1861 in the Oölitic slate of Solenhofen in Bavaria. This has a long lizard-like tail of twenty vertebræ, from each of which springs a well-developed feather on each side; feathers of the wings are also well preserved; bones of the hand are not fused together, as they are in recent Birds; and the jaws bear true teeth. This Bird has served as the basis of one of the primary divisions of the class *Aves*; though it has many reptilian characters, it is a true Bird. The great gap between this ancient Avian and latter-day birds has been to some extent bridged by the discovery and restoration of Birds from the Cretaceous formations of North America, such genera as *Ichthyornis* and *Hesperornis* forming types of

FIG. 14.—Oldest known ornithological treatise, illustrating also the art of lithography in the Jurassic period, engraved by *Archæopteryx lithographica*. From the original slab in the British Museum; after A. Newton, *Ency. Brit.*

two other primary divisions of the class, *Odontotormæ* and *Odontolcæ*, or Birds with teeth in sockets, and those with teeth in grooves. In both these genera the tail is short, as in ordinary birds. In *Ichthyornis*, though the wings are well developed, with fused metacarpals,

FIG. 15.—Restoration of *Hesperornis regalis*. After Marsh.

and the sternum is keeled, the vertebræ present the extraordinary primitive character of being biconcave. In *Hesperornis* the vertebræ are saddle-shaped, as usual, but the sternum is flat, as in the existing ostriches, and the wings are rudimentary, wanting metacarpals. Some twenty species of several genera of other American Cretaceous

Birds have been described. Remains of Birds multiply in the next period, the Tertiary. Those of the Eocene or early Tertiary are largely and longest known from discoveries made in the Paris Basin, among them the *Gastornis parisiensis*, at

FIG. 16.—Restoration of *Ichthyornis victor*. After Marsh.

least as large as an ostrich; some of these belong to extinct genera, others to genera which still flourish; none are known to have true teeth, or otherwise to be as primitive as the reptile-like forms of the Cretaceous. The Miocene or Middle Tertiary has proved specially rich in remains of Birds, including some of extinct

genera, but in largest proportion referable to modern types. Later Tertiary (Pliocene and Post-pliocene) birds are almost all of living genera, and some are apparently of living species. Extinct birds coeval with man, their bones bearing his marks, are found in various caves. Sub-fossil birds' bones occur in shell-heaps (kitchen-middens) and elsewhere, of course contemporaneous with man, and some of them scarcely prehistoric. One of the oldest of these is the gigantic *Æpyornis maximus* of Madagascar, of which we have not only the bones, but the egg. The immense Moas, or *Dinornithes* of New Zealand, were among the later of these to die, portions of skin, feathers, etc., of these great creatures having been found. With the Moa-remains are found those of *Harpagornis*, a raptorial bird large enough to have preyed upon the Moas. Finally, various birds have been exterminated in historic times, and some of them within the lifetime of persons now living. The Dodo of Mauritius, *Didusineptus*, is the most celebrated one of these, of the living of which we have documentary evidence down to 1681; the Solitaire of Rodriguez, *Pezophaps solitarius*, the Géant, *Leguatia gigantea*, and several others of the same Mascarene group of islands, are in similar case. The Great Auk, *Alca impennis*, is supposed to have become extinct in 1844; a species of Parrot, *Nestor productus*, was last known to be living in 1851; various parrots and other birds have likewise disappeared within a very few years. At least one North American bird, the Labrador Duck, *Camptolæmus labradorius*, seems likely soon to follow. (A. Newton, *Ency. Brit.* ninth edition, art. 'Birds.')

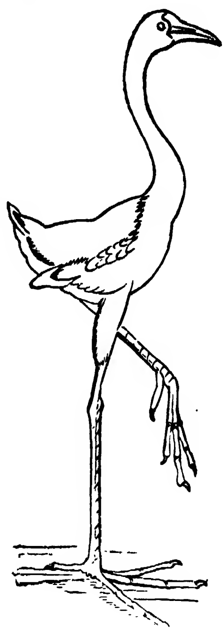


FIG. 17. — Restoration of *Leguatia gigantea*. After Schlegel.

§ 2.—PRINCIPLES AND PRACTICE OF CLASSIFICATION

Having seen what a Bird is, and how it is distinguished from other animals, our next business is to inquire how birds are related to and distinguished from one another, as the basis of

Classification: a prime object of ornithology, without the attainment of which birds, however pleasing they are to the senses, do not satisfy the mind, which always strives to make orderly

disposition of its knowledge, and so discover the reciprocal relations and interdependencies of the things it knows. Classification presupposes that there do exist such relations, according to which we may arrange objects in the manner which facilitates their comprehension, by bringing together what is like, and separating what is unlike; and that such relations are the results of fixed, inevitable law. It is, therefore,

Taxonomy (Gr. τάξις, *taxis*, arrangement, and νόμος, *nomos*, law), or the rational, lawful disposition of observed facts. Just as taxidermy is the art of fixing a bird's skin in a natural manner, so taxonomy is the science of arranging birds in the most natural manner; in the way that brings out most clearly their natural affinities, and so shows them in their proper relations to one another. This is the greatest possible help to the memory in its attempt to retain its hold upon great numbers of facts. But taxonomy, which involves consideration of the greatest problems of ornithology, as of every other branch of biology (*biology* being the science of life and living things in general), is beset with the gravest difficulties, springing from our defective knowledge. We could only perfect our taxonomy by having before us a specimen of every kind of bird that exists, or ever existed; and by thoroughly understanding how each is related to and differs from every other one. This is obviously impossible; in point of fact, we do not know all the birds now living, and only a small number of extinct birds have come to light; so that many of the most important links in the chain of evidence are missing, and many more cannot be satisfactorily joined together. With these springs of ignorance and sources of error must be reckoned also the risk of going wrong through the natural fallibility of the mind. The result is, that the "natural classification," like the elixir of life or the philosopher's stone, is a goal still distant; and as a matter of fact, the present state of the ornithological system is far from being satisfactory. It is obvious that birds, or any other objects, may be classified in numberless ways, —in as many ways as are afforded by all their qualities and relations,—to suit particular purposes, or to satisfy particular bents of mind. Hence have arisen, in the history of the science, very many different schedules of classification; in fact, nearly every leader of ornithology has in his time proposed his own system, and enjoyed a more or less respectable and influential following. Systems have been based upon this or that set of characters, and erected from this or that preconception in the mind of the systematist. Down to quite recent days, the modifications of the external parts of birds, particularly of the bill, feet, wings, and tail, were almost exclusively employed for purposes of classification; and the mental point of view was, that each species of bird was a separate creation, and as

much of a fixture in Nature's museum as any specimen in the naturalist's cabinet. Crops of classifications have been sown in the fruitful soil of such blind error, but no lasting harvest has been reaped. The confusion thus engendered has brought about the inevitable reaction; and the fashion of the present day is decidedly the opposite extreme,—that of counting external features of little consequence in comparison with anatomical characters. Too much time has been wasted in arguing the superiority of each of these characters for the purposes of classification; as if a natural classification should not be based upon all points of structure! as if internal and external characters were not reciprocal and mutually exponent of each other! But the genius of modern taxonomy seems to be so certainly right,—to be tending so surely, even if slowly, in the direction of the desired consummation, that all differences of opinion, we may hope, soon will be settled, and defect of knowledge, not perversity of the mind, be the only obstacle left in the way of success. The taxonomic goal is not now to find the way in which birds may be most conveniently arranged, described, and catalogued; but to discover their pedigree, and so construct their family-tree. Such a genealogical table, or *phylum* (Gr. φῦλον, *phulon*, tribe, race, stock), as it is called, is rightly considered the only taxonomy worthy the name,—the only true or natural classification. In attempting this end, we proceed upon the belief that, as explained above, all birds, like all other animals and plants, are related to each other genetically, as offspring are to parents; and that to discover their genetic relationships is to bring out their true affinities,—in other words, to reconstruct the actual taxonomy of Nature. In this view, there can be but one natural classification, to the perfecting of which all increase in our knowledge of the structure of birds infallibly tends. The classification now in use, or coming into use, is the result of our best endeavours to accomplish this purpose, and represents what approach we have made to this end. It is one of the great corollaries of that theorem of Evolution which most naturalists are satisfied has been demonstrated. It is necessarily a

Morphological Classification; that is, one based solely upon consideration of structure or form (μορφή, *morphē*, form); and for the following reasons: Every offspring tends to take on precisely the structure or form of its parents, as its natural physical heritage; and the principle involved, or the *law of heredity*, would, if nothing interfered, keep the descendants perfectly true to the physical characters of their progenitors; they would "breed true" and be exactly alike. But counter-influences are incessantly operative, in consequence of constantly varying external conditions of environment; the plasticity of organisation of all creatures rendering them

more or less susceptible of modification by such means, they become unlike their ancestors in various ways and to different degrees. On a large scale is thus accomplished, by *natural selection* and other natural agencies, just what man does in a small way in producing and maintaining different breeds of domestic animals. Obviously, amidst such ceaselessly shifting scenes, degrees of likeness or unlikeness of physical structure indicate with the greatest exactitude the nearness or remoteness of organisms in kinship. Morphological characters derived from examination of structure are therefore the surest guides we can have to the blood-relationships we desire to establish; and such relationships are the natural affinities which all classification aims to discover and formulate. As already said, taxonomy consists in tracing pedigrees, and constructing the *phylum;* it is like tracing any leaf or twig of a tree to its branchlet, this to its bough, this again to its trunk or main stem. The student will readily perceive, from what has been said, the impossibility of naturally arranging any considerable number of birds in any linear series of groups, one after the other. To do so means nothing more or less than the mechanical necessity of book-making, where groups have to succeed one another, in writing page after page. Some groups will follow naturally; others will not; no connected chain is possible, because no such single continuous series exists in nature. In cataloguing, or otherwise arranging a series of birds for description, we simply begin with the highest—or lowest, if we prefer—groups, and make our juxtapositions as well as we can, in order to have the fewest breaks in the series.

Morphology being the safest, indeed the only safe, clue to natural affinities, and the key to all rational classification, the student cannot too carefully consider what is meant by this term, or too sedulously guard against misinterpreting morphological characters, and so turning the key the wrong way. The chief difficulty he will encounter comes from *physiological adaptations of structure;* and this is something that must be thoroughly understood. The expression means that birds, or any animals, widely different in the sum of their morphological characters, may have certain parts of their organisation modified in the same way, thus bringing about a seemingly close resemblance between organisms really little related to each other. For example: a phalarope, a coot, and a grebe, all have lobate feet; that is, their feet are fitted for swimming purposes in the same way, namely, by development of flaps or lobes on the toes. A striking but very superficial and therefore unimportant resemblance in a certain particular exists between these birds, on the strength of which they used to be classed together in a group called *Pinnatipedes*, or "fin-footed" birds. But, on sufficient examination, these three birds are found to be very unlike in other

respects; the sum of their unlikenesses requires us to separate them quite widely in any natural system. The group *Pinnatipedes* is therefore unnatural, and the appearance of affinity is proved to be deceptive. Such resemblance in the condition of the feet is simply functional, or physiological, and is not correspondent with structural or morphological relationships. The relation, in short, between these three birds is *analogical;* it is an inexact superficial resemblance between things profoundly unlike, and therefore having little *homological* or exact relationship. *Analogy* is the apparent resemblance between things really unlike,—as the wing of a bird and the wing of a butterfly, as the lungs of a bird and the gills of a fish. *Homology* is the real resemblance or true relation between things, however different they may appear to be,—as the wing of a bird and the foreleg of a horse, the lungs of a bird and the swim-bladder of a fish. The former commonly rests upon mere functional, *i.e.* physiological, modifications; the latter is grounded upon structural, *i.e.* morphological, identity or unity. Analogy is the correlative of physiology, homology of morphology; but the two may be coincident, as when structures identical in morphology are used for the same purposes and are therefore physiologically identical. Physiological diversity of structure is incessant, and continually interferes with morphological identity of structure, to obscure or obliterate the indications of affinity the latter would otherwise express clearly. It is obvious that birds might be classified physiologically, according to their adaptive modifications or analogical resemblances, just as readily as upon any other basis: for example, into those that perch, those that walk, those that swim, etc.; and, in fact, most early classifications largely rested upon such considerations. It is also evident, that when functional modifications happen to be *coincident* with structural affinities,—as when the turning of the lower larynx into a music-box coincides with a certain type of structure,—such modifications are of the greatest service in classification, as corroborative evidence. But since all sound taxonomy rests on morphology, on real structural affinity, we must be on our guard against those physiological "appearances" which are proverbially "deceptive." I trust I make the principle clear to the student. Its practical application is another matter, only to be learned in the school of experience. This matter of

Homology or Analogy may be thus summed: Birds are *homologically related,* or naturally allied or affined, according to the sum of like structural characters employed for similar purposes; they are *analogically related,* only according to the sum of unlike characters employed for similar purposes. A loon and a cormorant, for instance, are closely affined, because they are both fitted in the same way for the pursuit of their prey by flying under water. A

dipper (family *Cinclidæ*) and a loon (family *Colymbidæ*) are analogous, in so far as both are fitted to pursue their prey by flying under water; but they stand near opposite extremes of the ornithological system; they have little affinity beyond their common birdhood—very different structure being modified to attain the same end. So again, conversely, the crow has vocal organs almost identical in structure with those of the nightingale, and the organisation of the two birds is in other respects very similar; their affinity or homology is therefore close, though the crow is a hoarse croaker, the nightingale an impassioned musician.

The Reason why Morphological Classification is so important as to justify or even require its adoption has been very clearly stated by Huxley, whose words I cannot do better than quote in this connection. Speaking of animals, not as physiological apparatuses merely; not as related to other forms of life and to climatal conditions; not as successive tenants of the earth; but as fabrics, each of which is built upon a certain plan, he continues: "It is possible and conceivable that every animal should have been constructed upon a plan of its own, having no resemblance whatever to the plan of any other animal. For any reason we can discover to the contrary, that combination of natural forces which we term Life might have resulted from, or been manifested by, a series of infinitely diverse structures; nor would anything in the nature of the case lead us to suspect a community of organisation between animals so different in habit and in appearance as a porpoise and a gazelle, an eagle and a crocodile, or a butterfly and a lobster. Had animals been thus independently organised, each working out its life by a mechanism peculiar to itself, such a classification as that now under contemplation would be obviously impossible; a morphological or structural classification plainly implying morphological or structural resemblances in the things classified.

"As a matter of fact, however, no such mutual independence of animal forms exists in nature. On the contrary, the members of the animal kingdom, from the highest to the lowest, are marvellously connected. Every animal has something in common with all its fellows; much, with many of them; more, with a few; and usually, so much with several, that it differs but little from them.

"Now, a morphological classification is a statement of these gradations of likeness which are observable in animal structures, and its objects and uses are manifold. In the first place, it strives to throw our knowledge of the facts which underlie, and are the cause of, the similarities discerned, into the fewest possible general propositions, subordinated to one another, according to their reater or less degree of generality; and in this way it answers the purpose of a *memoria technica*, without which the mind would be

incompetent to grasp and retain the multifarious details of anatomical science.

"But there is a second and even more important aspect of morphological classification. Every group in that classification is such in virtue of certain structural characters, which are not only common to the members of the group, but distinguish it from all others; and the statement of these constitutes the definition of the group.

"Thus, among animals with vertebræ, the class *Mammalia* is definable as those which have two occipital condyles, with a well-ossified basi-occipital; which have each ramus of the mandible composed of a single piece of bone and articulated with the squamosal element of the skull; and which possess mammæ and non-nucleated red blood-corpuscles.

"But this statement of the characters of the class *Mammalia* is something more than an arbitrary definition. It does not merely mean that naturalists agree to call such and such animals *Mammalia;* but it expresses, firstly, a generalisation based upon, and constantly verified by, very wide experience; and, secondly, a belief arising out of that generalisation. The generalisation is that, in nature, the structures mentioned are always found associated together; the belief is that they always have been, and always will be, found so associated. In other words, the definition of the class *Mammalia* is a statement of a law of correlation, or coexistence, of animal structures, from which the most important conclusions are deducible" (Introd. to *Classif. of Animals*, 8vo, London, 1869, pp. 2, 3).

But broad as such laws of correlation of structure are, and important as are the conclusions deducible, we must constantly be on our guard against presuming upon the infallibility either of the data or of the deduction, as the author just quoted goes on to show. Such caution is specially required where there is no obvious reason for the particular combination that may be found to exist. In the case of the ostrich-like birds (*Ratitæ*), for example, we can understand how a flat, unkeeled breast-bone, a particular arrangement of the shoulder-bones, and a rudimentary state of the wing-bones, are found in combination, because all these modifications of structure are evidently related to loss of the power of flight; and, in point of fact, no exception is known to the generalisation, that such conditions of the sternal, coraco-scapular, and humeral bones always coexist. But in all known struthious (ratite) birds, this state of the bones in mention coexists also with a peculiar modification of the bones of the palate, and no necessary connection between these two sets of diverse characters is conceivable. Now, if we only knew struthious birds, and found the combination in mention to hold with them all, we should doubtless declare our belief that any

bird having such palatal characters would also be found to possess such imperfect wing-apparatus. But this would be going too far: in fact, we know that the tinamous (*Dromæognathæ*) have such a palate, yet have a keeled sternum and functionally developed wings. The real use and proper application of such generalisations is to teach the lesson, that creatures exhibiting such modified combinations of characters are genetically related to each other just in the degree to which they possess characters in common, and are genetically remote from each other in the degree to which they do not possess characters in common: *i.e.* that their similarities and distinctions of structure are sure indexes of their natural affinities. To take another case, derived from consideration of a large number of existing birds: it is an observed fact, that a particular arrangement of the plates upon the back of the tarsus, a peculiar modification of the lower larynx or voice organ, and an undeveloped or abortive condition of the first large feather on the hand, are found associated in a vast series of birds, constituting the group of *Passeres* called *Oscines*. What possible connection there can be between these three separate and apparently independent modifications we cannot even surmise; but that they have some natural and necessary connection we cannot doubt, and that the connection is causal, not fortuitous, is a logical inference from the observed fact, that birds which present this particular combination are also closely related in other structural characters; that is, that they have all been subjected to operative influences which have conspired to produce the modifications observed. Given, then, a bird, with a known oscine larynx, but unknown as to its feet and wings, it would be a reasonable inference that these members, when discovered, would present the characters observed to occur in like cases. But the first lark (*Alaudidæ*) examined would show the inference to be fallible; for the tarsus of such a bird is differently disposed, though a lark has an elaborate singing apparatus, and only nine instead of ten developed primaries. Once more: the development of a keeled sternum, a peculiar saddle-shape of certain vertebræ, and lack of true teeth, are characters coexisting in all the higher birds; and, as far as these birds are concerned, we have no hint that such a combination is ever broken. In fact, however, the singular Cretaceous *Ichthyornis* shows us a pattern of bird in which a well-keeled sternum and perfectly formed wings coexist with teeth in reptile-like jaws and with fish-like biconcave vertebræ. What we learn from this case indeed breaks down one of the most precise definitions we might have made (and indeed did make) respecting birds at large; but in its failure we are taught how great is the modification of geologically recent birds from their primitive generalised ancestry; we learn something likewise of the steps of such

modification, and of the length of time required for the process. It is the history of attempts to frame definitions of groups in zoology, that they are all liable to be negatived by new discoveries, and therefore to be broken down and require remodelling as our knowledge increases. It is to be readily perceived that the ability to draw distinctions and make definitions of groups is as much the *gauge of our ignorance* as the test of our knowledge; for all groups, like all species, come to be such by modification so gradual, so slight in each successive increment of difference, that, if all the steps of the process were before our eyes, we should be able to limit no groups whatever in a positive, unqualified manner. All would merge insensibly into one another, be inseparably linked in as many series as there have been actual lines of evolutionary progress, and finally converge to the one or few starting-points of organised beings.

Practically, however, the case is quite the reverse,—happily for the comfort of the working naturalist, however sadly the philosopher may deplore the ignorance implied. Degrees of likeness and unlikeness do exist, which when rightly interpreted enable us to mark off groups of all grades with much facility and precision, and thus erect a morphological classification which recognises and defines such degrees, and explains them upon the principles of Evolution. The way in which the principles of such classification are to be practically applied gives occasion for some further remarks upon

Zoological Characters.—A "character," in zoological language, is any point of structure which may be perceived and described for the purpose of comparing or contrasting animals with one another. Thus, the conditions of the sternum, palate, tarsus, larynx, as noted in preceding paragraphs, are each of them characters which may be used in describing individual birds, or in framing definitions of groups of birds. Morphological characters, with which the classification we have adopted alone concerns itself, may be derived from the structure of a bird considered in any of its relations, or as affected by any of the conditions to which it is subjected. Thus *embryological* characters are those afforded by the bird during the progress of its development in the egg, from the almost structureless germ to the fully formed chick. Such characters of the embryo in its successive stages are of the utmost significance; for it is a fact that the germ of each of the higher organisms goes through a series of developmental changes which, at each succeeding step in the unfolding of its appropriate plan of structure, causes it to resemble the adult state of animals lower than itself in the scale of organisation. In fine, the history of the evolution of every *individual* bird epitomises the history of those changes which birds collectively have undergone in becoming what

they are by modified descent from lower organisms. Such transitory stages of any embryo, therefore, give us glimpses of those evolutionary processes which have affected the group to which it belongs. Any bird, for example, when a germ, is at first on the plane of organisation of the very lowest known creatures,—one of the *Protozoa*, or single-celled animals. As its germ develops, and its structure becomes more complicated by the formation of parts and organs successively differentiated and specialised, it rises higher and higher in the scale of being. At a certain stage very early reached (for the steps by which it becomes like any invertebrate are very speedily passed over) it resembles a fish in possessing gill-like slits, several aortic arches, no true kidneys, no amnion, etc. Further advanced, losing its gills, gaining kidneys and amnion, etc., it rises to the dignity of a reptile, and at this stage it is more like a reptile than like a bird; having, for example, a number of separate bones of the wrist and ankle, no feathers, etc. The assumption of its own appropriate characters, *i.e.* those by which it passes from a reptilian creature to become a bird, is always the last stage reached. We can thus actually see and note, inside any egg-shell, exactly those progressive steps of development of the individual bird which we believe to have been taken on a grand scale in nature for the evolution of the class *Aves* from lower forms of life; and the lesson learned is fraught with significance. It is nothing less than the demonstration in *ontogeny* (genesis of the individual) of that *phylogeny* (genesis of the race) by which groups of creatures come to be. The interior of any adult bird, again, furnishes us with all kinds of ordinary *anatomical* characters, derived from the way we perceive the different organs and systems of organs to be fashioned in themselves, and arranged with reference to one another. The finishing of the outward parts of a bird gives us the ordinary *external* characters, in the way in which the skin and its appendages are modified to form the covering of the bill and feet, and to fashion all kinds of feathers. Birds being of opposite sexes, and such difference being not only indicated in the essential sexual organs, but usually also in modifications in size or shape of the body or quality of the plumage and other outgrowths, a set of *sexual* characters are at our service. Birds are also sensibly modified in their outward details of feathering by times of the year when the plumage is changed, and this renders appreciation of *seasonal* characters possible. All such circumstances, and others that could be mentioned, such as effects of climate, of domestication, etc., in so far as they in any way affect the structure of birds, conspire to produce zoological characters, as these are above defined. Such characters, according as they result from more or less profound impressions made upon the organism, are of more or less "value"

in taxonomy; being of all grades, from the trivial ones that serve to distinguish the nearest related species or varieties, to the fundamental ones that serve to mark off primary divisions. Thus the "character" of possessing a backbone is common to all animals of an immense series called *Vertebrata.* The "character" of feathers is common to all the class *Aves;* of toothless jaws to all modern birds; of a keeled sternum to all the sub-class *Carinatæ;* of feet fitted for perching to all the order *Passeres;* of a musical apparatus to all the sub-order *Oscines;* of nine primaries to all the family *Fringillidæ;* of crossed mandibles to all of the genus *Loxia;* of white bands on the wings to all of the species *Loxia leucoptera.* There is thus seen a sliding scale of valuation of characters, from those involving the most profound or *primitive* modifications of structure to those resting upon the most superficial or *ultimate* impressions. It will also be obvious that every ulterior modification presupposes inclusion of all the prior ones; for a white-winged crossbill, to be itself, must be a loxian, fringilline, oscine, passerine, carinate, modern, avian, vertebrated animal. The more characters, of all grades, that any birds share in common, the more closely are they related, and conversely. Obviously, the possession of more or fewer characters in common results in

Degrees of Likeness.—Were all birds alike, or did they all differ by the same characters to the same degree, no classification would be possible. It is a matter of fact that they do exhibit all degrees of likeness possible within the limits of their Avian nature; it is a matter of belief that these degrees are the necessary result of Evolution—of descent with modification from a common ancestry; and that, being dependent upon that process, they are capable of explaining it if rightly interpreted. For example: Two white-winged crossbills, hatched in the same nest, scarcely differ perceptibly (except in sexual characters) from each other, and from the pair that laid the eggs. We call them "specifically" identical; and the sum of the differences by which they are distinguished from any other kinds of crossbills is their "specific character." All the individual crossbills which exhibit this particular sum constitute a "species." In this case, the genetic relationship of offspring and parent is unquestionable—it is an observed fact. Now turn to the extremely opposite case. The difference between our crossbills and the Cretaceous *Ichthyornis* is enormous: I suppose it is nearly the greatest known to subsist between any two birds whatsoever. But the *Ichthyornis* and the *Loxia* are also separated by a correspondingly immense interval of *time,* and presumably by correspondingly enormous differences in *conditions of environment*—in their physical surroundings. It is a logical inference that these two things—difference in physical structure and difference in

physical environment—are in some way correlated and co-ordinated. If we presume, upon the theory of evolution, that, despite the great difference, a crossbill is genetically related to some such bird as an *Ichthyornis*, as truly as it is to its actual parents, only much more remotely, and that the difference is due to modifications impressed upon its stock in the course of time, conformably with changing conditions of environment, we shall have a better explanation of the difference than any other as yet offered—an explanation, moreover, which is corroborated by all the related facts we know, and with which no known facts are irreconcilable. But to correctly gauge and formulate the degrees of likeness or unlikeness between any two birds is to correctly "classify" them; and if these degrees rest, as we believe they do, upon nearness or remoteness of genetic relationship, classification upon such basis becomes the truest attainable formulation of "natural affinities." It is the province of morphological classification to search out those natural affinities which the structure of birds indicates, and express them by dividing birds into groups, and subdividing these into other groups, of greater or lesser value or grade, according to the fewer or more characters shared in common,—that is, according to degrees of likeness; that is, again, according to genealogical relationship or consanguinity.

Zoological Groups.—To carry any scheme of classification into practical effect, naturalists have found it necessary to invent and apply a system of grouping objects whereby the like may come together and be separated from the unlike. They have also found it expedient to give names to all these groups, of whatever grade, such as *class*, *order*, *family*, *genus*, *species*, etc.; and to stamp each such group with the value of its grade, or its relative rank in the scale, so that it may become currency among naturalists. The student must observe, in the first place, that the value of each such coinage is wholly arbitrary, until sanctioned and fixed by common consent. The term "class," for example, simply indicates that naturalists agree to use that word to designate a conventional group of a particular grade or value. Indispensable as is some such acceptable medium of exchange of ideas among naturalists, their groups are *not* fixed, have *no* natural value, and in fact have no actual existence in the treasury of Nature. It cannot be too strongly impressed upon the student that Nature makes no bounds,—*Natura non facit saltus;* there are no such abrupt transitions in the unfolding of Nature's plan, no such breaks in the chain of being, as he would be led to suppose by our method of defining and naming groups. He must consider the words "class," "order," etc., as wholly arbitrary terms, invented and designed to express our ideas of the relations which subsist between any animals or sets of animals. Thus, for

example, by the term the "Class of Birds" we signify simply the kind and degree of likeness which all birds share, such being also the kind and degree of their unlikeness from any other animals; the word "class" being simply the name or handle of the generalisation we make respecting their relations with one another and with other animals; it represents an abstract idea, is the expression of a relation. True, all birds *embody* the idea; but "class" is nevertheless an abstraction. Now, as intimated earlier in this essay, the definition of the idea we attach to the term—the limitation of the class *Aves*—depends entirely upon how much we know of the relation intended to be expressed. It so happens that no animals are known which cannot be decided to belong, or not to belong, to the conventional class of birds, because we have found it convenient and expedient to consider the presence of feathers a fair criterion or necessary qualification. But what, when an animal is discovered the covering of whose body is half-way between the scales of a lizard and the plumes of a bird, and whose structure is otherwise as equivocal? This may happen any day. A feather is certainly a modified scale; a feather has doubtless been developed out of a scale. In the case supposed, we should have to modify our definition of the "Class of Birds"; that is, change our ideas upon the subject, and alter the boundary-line we established between the classes of birds and reptiles; whereas, were a "class" something naturally definite, independent, and fixed, all that we could learn about it would only tend to establish it more surely. The same obscurity and uncertainty of definition attaches to groups of every grade—from the Animal "Kingdom" itself, which cannot be cut clear of the Vegetable "Kingdom"—down through classes, orders, families, genera, species, and varieties—yes, to the *individual* itself, which, however unmistakable among higher organisms, cannot always be predicated of the lowermost forms of Life. Such divisions, of whatever grade, as we are able to establish for the purposes of classification, depend entirely upon the breaks and defects in our knowledge. There is no such thing as drawing hard-and-fast lines anywhere, for none such exist in Nature.

Taxonomic Equivalence of Groups.—But, however arbitrary they may be, or however obscure or fluctuating may be their boundaries, groups we must have in zoology, and groups of different grades, to express different degrees of likeness of the objects examined, and so to classify them. It is a great convenience, moreover, to have a recognised sliding-scale of valuation of groups from the highest to the lowest, and an accepted valuation. Just as in a thermometric scale, there are degrees designated as those of the boiling-point of water, the heat of the blood, the freezing of water, of mercury, etc.; so there are certain degrees of likeness

conventionally designated as those of *class*, *order*, *family*, *genus*, and *species;* always accepted in the order here given, from higher to lower groups. (There are various others, and especially a number of intermediate groups, generally distinguished by the prefix *sub-*, as *sub-family;* but those here given are generally adopted by English-speaking naturalists, and suffice to illustrate the point I wish to make.) It may sound like a truism to say that groups of the same grade, bearing the same name, whatever that may be, must be of the same value,—must be based upon and distinguished by characters of equal or equivalent importance. *Equivalence of groups* is necessary to the stability and harmony of any classificatory system. It will not do to frame an order upon one set of characters here, and there a family upon a similar set of characters; but order must differ from order, and family from family, by an equal or corresponding amount of difference. Let a group called a family differ as much from the other families in its own order as it does from some other order, and by this very circumstance it is not a family but an order itself. It seems a very simple proposition, but it is too often ignored, and always with practical ill result. Two points should be remembered here: First, that absolute size or numerical bulk of a group has nothing to do with its taxonomic value: one order may contain a thousand species, and another be represented by a single species, without having its ordinal valuation affected thereby. Secondly, any given character may assume different importance, or be of different value, in its application to different groups. Thus, the number of primaries, whether nine or ten, is a family character almost throughout *Oscines;* but in one oscine family (*Vireonidæ*) it has scarcely generic value. It is difficult, however, to determine such a point as this without long experience. Nor is it possible, in fact, to make our groups correspond in value with entire exactitude. The most we can hope for is a reasonable approximation. As in the thermometric simile above given, "blood-heat" and other points fluctuate, so does order not always correspond with order, nor family with family, in actual significance. What degree of difference shall be "ordinal"? What shall be a difference of "family"? What shall be "generic" and what "specific" differences? Such questions are more easily asked than answered. They demand critical consideration.

Valuation of Characters.—In a general way, of course, the greater the difference between any two objects, the more "important" or "fundamental" are the "characters" by which they are distinguished. But what makes a character "important" or the reverse? Obviously, what it signifies represents its importance. We are classifying morphologically, and upon the theory of Evolution; and in such a system a character is important or the reverse,

simply as an exponent of the principles, or an illustration of the facts, of evolutionary processes of Nature, according to the unfolding of whose plans of animal fabrics the whole structure of living beings has been built up. Why is the possession of a backbone such a "fundamental" character that it is used to establish one of the primary branches of the animal kingdom? It is not because so many millions of creatures possess it, but because it was introduced so early in the evolutionary process, and because its introduction led to the most profound modification of the whole structure of the animals which became possessed of a vertebral column. Why is the possession by a bird of biconcave vertebræ so significant? Not because all modern birds have saddle-shaped vertebræ, but because to have biconcave vertebræ is to be *quoad hoc* fish-like. Why is presence or absence of teeth so important? Not that teeth served those old birds better than a horny beak serves modern ones, but because teeth are a reptilian character. Obviously, to be fish-like or reptile-like is to be by so much unbirdlike; the degree of difference thus indicated is enormous; and a character that indicates such degree of difference is proportionally "important" or "fundamental," —just what we were after. By knowledge of facts like these, and by the same process of reasoning, a naturalist of tact, sagacity, and experience is able to put a pretty fair valuation upon any given character; he acquires the faculty of perceiving its significance, and according to what it signifies does it possess for him its taxonomic importance. As a matter of fact, it seems that characters of all sorts are to be estimated *chronologically*. For, if animals have come to be what they are by any process that took time to be accomplished, the characters earliest established are likely to be the most fundamental ones, upon the introduction of which the most important train of consequences ensue. Feathers, for example, as the *Archæopteryx* teaches us, were in full bloom in the Jurassic period, and they are still the most characteristic possession of birds: all birds have them; they are a class character. If they had been taken on quite recently, we may infer that many creatures otherwise entirely avian might not possess them, and they would have in classification less significance than that now rightly attributed to them. On the other hand, we cannot suppose that the finishing touches, by which, in the presence of white bands on the wings of *Loxia leucoptera*, and their absence in *Loxia curvirostra*, these two "species" are distinguished, were not very lately given to these birds. It is a very late step in the process, and correspondingly insignificant; it is of that value or importance which we call "specific." The same method of reasoning is available for determining the value of any character whatever, and so of estimating the grade of the group which we establish upon such character. As a rule,

therefore, the length of time a character has been in existence, and its taxonomic value, are correlated, and each is the exponent of the other.

"Types of Structure."—In no department of natural history has the late revolution in biological thought been more effective than in remodelling, presumably for the better, the ideas underlying classification. In earlier days, when "species" were supposed to be independent creations, it was natural and almost inevitable to regard them as fixed facts in nature. A species was as actual and tangible as an individual, and the notion was, that, given any two specimens, it should be perfectly possible to decide whether they were of the same or different species, according to whether or not they answered the "specific characters" laid down for them. The same fancy vitiated all ideas upon the subject of genera, families, and higher groups. A "genus" was to be discovered in nature, just like a species; to be named and defined. Then species that answered the definition were "typical"; those that did not do so well were "sub-typical"; those that did worse were "aberrant." A good deal was said of "types of structure," much as if living creatures were originally run into moulds, like casting type-metal, to receive some indelible stamp; while—to carry out my simile—it was supposed that by looking at some particular aspect of such an animal, as at the face of a printer's type, it could be determined in what box in the case the creature should be put; the boxes themselves being supposed to be arranged by Nature in some particular way to make them fit perfectly alongside each other by threes or fives, or in stars and circles, or what not. How much ingenuity was wasted in striving to put together such a Chinese puzzle as these fancies made of Nature's processes and results, I need not say; suffice it, that such views have become extinct, by the method of natural selection, and others, apparently better fitted to survive, are now in the struggle for existence. Rightly appreciated, however, the expression which heads this paragraph is a proper one. There are numberless "types of structure." It is perfectly proper to speak of the "vertebrate type," meaning thereby the whole plan of organisation of any vertebrate, if we clearly understand that such a type is not an independent or original model conformably with which all backboned animals were separately created, but that it is one modification of some more general plan of organisation, the unfolding of which may or did result in other besides vertebrated animals; and that the successive modifications of the vertebrate plan resulted in other forms, equally to be regarded as "types," as the reptilian, the avian, the mammalian. Upon this understanding, a group of any grade in the animal kingdom is a "type of structure," of more general or more special significance, presumably

according to the longer or shorter time it has been in existence. An individual specimen is "typical" of a species, a species is "typical" of a genus, etc., if it has not had time enough to be modified away from the characters which such species or genus expresses. Any set of individuals, that is, any progeny, which become modified to a degree from their progenitors, introduce a new type; and continually increasing modification makes such a type specific, generic, and so on, in succession of time. There must have been a time, for example, when the Avian and Reptilian "types" began to diverge from each other, or, rather, to branch apart from their common ancestry. In the initial step of their divergence, when their respective types were beginning to be formed, the difference may have been infinitesimal. A little farther along, the increment of difference became, let us say, equivalent to that which serves to distinguish two species. Wider and wider divergence increased the difference, till genera, families, orders, and finally the classes of *Reptilia* and *Aves*, became established. In one sense, therefore,—and it is the usual sense of the term,—the "type" of a bird is that one which is *farthest removed from* the reptilian type,—which is most highly specialised by differentiation to the last degree from the characters of its primitive ancestors. One of the *Oscines*, as a thrush or sparrow, would answer to such a type, having lost the low, primitive, generalised structure of its early progenitors, and acquired very special characters of its own, representing the extreme modification which the stock whence it sprang has undergone. In a broader sense, however, the type of a bird is simply the stock from which it originated: and in such sense the highest birds are the least typical, being the farthest removed and the most modified derivatives of such stock, the characters of which are consequently remodelled and obscured to the last degree. Two opposite ideas have evidently been confused in the use of the word "Type." They may be distinguished by inventing the word *teleotype* (Gr. τέλεος, *teleos*, final, *i.e.* accomplished or determined; formed like *teleology*, etc.) in the usual sense of the word type; and using the word we already possess, *prototype* (Gr. πρῶτος, *protos*, first, leading, determining), in the broader sense of the earlier plan whence any teleotype has been derived by modification. Thus, *Ichthyornis* or *Archæopteryx* is prototypic of modern birds, any of which are teleotypic of their ancestors. It may be further observed that any form which is teleotypic in its own group is prototypic of those derived from it. Thus, the *Archæopteryx*, so prototypic of modern birds, was a very highly specialised teleotype of its own ancestry. A little reflection will also make it clear that the same principle of antitypes (opposed types) is applicable to any of our groups in zoology. *Any group is teleotypic of the next greater group of which it is a member; prototypic of*

the next lesser one. Any species is teleotypic of its genus; any genus, of its family; any family, of its order; and conversely; that is to say, any species represents one of the ulterior modifications of the plan of its genus. The Class of Birds, for example, is one of the several teleotypes of Vertebrata, *i.e.* of the vertebrate plan of structure; representing, as it does, one of several ways in which the vertebrate prototype is accomplished. Conversely, the Class of Birds is prototypical of its several orders, representing the plan which these orders severally unfold in different ways. And so on, throughout any series of animals, backward and forward in the process of their evolution: any given form being teleotypic of its predecessors, prototypic of its successors. All existing forms are necessarily teleotypic,—only prototypic for the future. Prototype, in the sense here conveyed, indicates what is often expressed by the word *archetype.* But the latter, as I understand its use by Owen and others, signifies an ideal plan never actually realised; the "archetype of the vertebrate skeleton," for example, being something no vertebrate ever possessed, but a theoretical model—a generalisation from all known skeletons. The correspondence of my use of "prototypic" with a common employment of "archetypic," and of "teleotypic" as including both "attypic" and "etypic," is noted below.[1]

The actual and visible genetic relationships of living forms being practically restricted to individuals of the same species,—parents and offspring specifically identical,—it would seem at first sight that species must be the modified descendants of their respective genera, in order to be teleotypic of any such next higher group. But nothing descends from a genus, or any other group; everything descends from individuals; a genus, like any other group, is an abstract statement of a relation, not a begetter of anything. To illustrate: the "genus *Turdus*" is represented, let us say, by a score of species: if these species be rightly allocated in the genus, they are all the modified descendants of a form which was, before they severally branched off, a specific form; and the "genus

[1] "*Archetypical* characters are those which a group derives from its progenitor, and with which it commences, but which in much modified descendants are lost; such, for example, is the dental formula of the Educabilia (M $\frac{3}{3}$ PM $\frac{4}{4}$ C $\frac{1}{1}$ 1 $\frac{3}{3} \times 2$), —a formula, as shown by Owen, very prevalent among early members of the group, but generally departed from more or less in those of the existing faunas. *Attypical* characters are those to the acquisition of which, as a matter of fact, we find that forms, in their journey to a specialised condition, tend. . . . *Etypical* characters are exceptional ones, and which are exhibited by an eccentric offshoot from the common stock of a group" (Gill, *Pr. Am. Assoc. Adv. Sci.*, xx. 1873, p. 293). To illustrate in birds: A generalised lizard-like type of sternum is *archetypic* of any bird's sternum. The sternum of the lizard-like animals whence birds actually descended is *prototypic;* the keeled sternum of a carinate bird is *attypical* in most birds, *etypical* in the peculiar state in which it is found in *Stringops;* but equally *teleotypic* in both instances.

Turdus" in the abstract is simply that form; and that form is prototypic of its derivatives. In the concrete, as represented by its teleotypes, the genus *Turdus* sums the modifications which these have collectively undergone, without specifying the particular modifications of any of them; it expresses the way in which they are all like one another, and in which they are all unlike the representatives of any other genus. Thus what is above advanced is seen to hold, though genera and all other groups are actual descendants of individuals specifically identical.

Generalised and Specialised Forms.—Taking any one group of animals—say the genus *Turdus*, of numerous species—and considering it apart from any other group, we perceive that it represents a certain assemblage of characters peculiar to itself, aside from those more fundamental ones it includes of its family, order, etc. Its particular characters we call "generic." Among the numerous teleotypic forms it includes, there is a wide range of specific variation, within the limits of generic relationship. Some of its species are modified farther away than some others are from the generic standard or type to which all conform more or less perfectly. The former, having more peculiarities of their own, are said to be the most *specialised;* the latter, having fewer peculiarities, are the least specialised. Those that are the least specialised are obviously the most *generalised;* and this means that we believe them to be nearest to the stock whence all have together descended with modification. The application of this illustration to great groups shows us the principle upon which any form is said to be *generalised* or *specialised.* The *Ichthyornis*, with its fish-like vertebræ, reptile-like teeth, bird-like sternum and shoulder-girdle, is a very generalised form. A thrush is the opposite extreme of a highly specialised form. The two are also separated by an enormous interval of time; one being very old, the other quite new; a chronological sequence is here perceived. Since the evolutionary processes concerned in the modification on the whole represent progress from simplicity to complexity of organisation, and therefore ascent in the scale of organisation, a *generalised* type, an *ancient* type, and a *simple* type are on the whole synonymous, and to be contrasted with forms *specialised*, *recent*, and *complex.* They therefore respectively correspond to

"Low" and "High" in the Scale of Organisation.—All existing birds are very closely related, notwithstanding the great numerical preponderance of the class in the present geological epoch. This outbreak, as it were, of birds upon the modern scene, is like the nearly simultaneous bursting into bloom of a mass of flowers at the end of one branch of the Sauropsidan stem. All modern birds, in fact, are strongly specialised forms, so much so that

it is difficult to predicate "high" or "low" within such a narrow scale. The great group *Passeres*, for example, comprehending a majority of all known birds, is scarcely more different from other birds than are the families of reptiles from each other, and among *Passeres* we have little to go upon in deciding "high" or "low" beyond the musical ability of *Oscines*. It is hard to see much difference in actual complexity of organisation between those birds regarded as the lowest, as an ostrich or a penguin, and those conceded to be highest, as a swallow or sparrow. Nevertheless, in a larger perspective, as between a fish, a reptile, and a bird, the student will readily perceive the bearing of the ideas attached to the terms "low" and "high" in the scale of organisation. Creatures rise in the scale by a number of correlated modifications and in the course of time (for it takes time to evolve a class of birds from sauropsidan stock as really as it does to develop the germ of an egg into the body of a chick). Progressive differentiation and specialisation of structure and function in due course elaborates diversity from sameness, complexity from simplicity, the "high" special from the "low" general plan of organisation; the culmination in man of the vertebrate type, first faintly foreshadowed in the embryonic Ascidian. No one should venture to foretell the result of infinitesimal increments in elevation of structure and function, nor presume to limit the infinite possibilities of evolutionary processes, either in this actual world or in a foretold next one.

As to "evidences of design" in the plan of organised beings, it may be said simply that every creature is perfectly "designed" or fitted for its appropriate activities, and perfectly adapted to its conditions of environment. In fact, it must be so fitted and adapted, or it would perish. Whether it so determines itself, or is so determined, is a teleological question. The truth remains that every creature is perfect in its own way. A worm is as perfectly fitted to be a worm, as is a bird to be a bird; in fact, were it not, it would either turn into something else, or cease to be. A spade is as perfect an organisation *of the spade kind*, as is the steam-engine of that kind of an organisation; though the difference in complexity of structure and functional capacity, like that between the lowly organised ascidian generality and the highly organised avian speciality, is enormous.

One word more: The class of mammals is highest in the scale of organisation. The class of birds is next highest. But it does not follow, from this relation sustained by *Mammalia* and *Aves* collectively, that every mammal must be more highly organised than every bird. It is difficult to say how a mole or a mouse is a more elaborate or more capable creature than a canary-bird, physically or mentally. The relative rank of two groups is determined

by balancing the aggregate of their structural characters. In large series, the average of development, not the extremes either way, is taken into account; so that the lowest members of a higher group may be below the highest members of the next lower group. The common phrase, "below par," or "above par," is most applicable to such cases.

Machinery of Classification.—The inexperienced student may be glad to be given some explanation of the way in which the taxonomic principles we have discussed are applied, and carried into practical effect in classifying birds. Our machinery for that purpose is our inheritance from those naturalists who held very different views from those which touch the evolutionary key-note of modern classification. It is clumsy, and does not work well as a means of expressing the relations we now believe to be sustained by all organisms toward one another; but it is the best we have. Systematic zoology, or the practice of classification, has failed to keep pace with the principles of the science; we are greatly in need of some new and sharper "tools of thought," which shall do for zoology what the system of symbols and formulæ has done for chemistry. *We want some symbolic formulation of our knowledge.* The invention of a practicable scheme of classification and nomenclature, which should enable us to formulate what we mean by *Turdus viscivorus*, as a chemist symbolises by SO_4H_2 what he understands hydrated sulphuric acid to be, would be an inestimable boon to working naturalists. The mapping out of groups with connecting lines to indicate their genetic relations, in the form of the phylum, is a common practice; but that, like any other pictorial representation of a "family tree," is not the graphic symbolisation required. The first steps in this direction have been tentatively taken already by the late Mr. A. H. Garrod and others: we already have a mother of the required invention in the necessity of the case, and may hope that the father will not be long in coming.

Under the present system, Birds are called a "Class" of Vertebrates, and are subdivided into "orders," "families," "genera," "species," and "varieties," as already sufficiently indicated. Groups intermediate to any of these may be recognised; and if so, are usually distinguished by the prefix *sub-*. Many other terms are in occasional use, as "tribe," "race," "series," "cohort," "super-family"; but the six first mentioned are the best established ones among English-speaking naturalists. Their sequence is fixed, as above, from higher to lower, in relative rank.[1] With the exceptions

[1] The expression "higher group," in the sense of relative rank in the taxonomic scale, will of course be distinguished from the same expression when applied to the relative rank in the scale of organisation of the objects classified. An order of birds is a "higher group" than a family of birds, in the former sense, but no higher than an order of worms, in the latter sense.

to be presently noted, the names of groups are arbitrary, at the will of the person who establishes and designates them. The framer of a genus, or the describer of a species, calls it what he pleases, and the name he gives holds, subject to certain statutory regulations which naturalists generally agree to abide by. The exceptions are the names of families and sub-families, the former commonly being made to end in *-idæ*, the latter in *-inæ*: family *Turdidæ;* sub-family *Turdinæ.* This is a great convenience, since we always know the rank intended to be noted by these word-forms. The names of groups higher than species are almost invariably single words; as, order *Passeres;* but sometimes, especially in cases of intermediate groups, two words are used, one qualifying the other; as, sub-order *Passeres Acromyodi*, or oscine Passeres. A generic or sub-generic name is always a single word; these, and the names of all higher groups, invariably begin with a capital letter.

Until quite recently, the scientific name of any individual bird almost invariably consisted of two terms, generic and specific,—the name of the genus, followed by the name of the species; as, *Turdus viscivorus*, for the missel-thrush. This is the "binomial nomenclature" (badly so called, for "binominal" or "bionymic" would be better); introduced by Linnæus in the middle of the last century. It was a great improvement upon the former method of giving either single arbitrary names to birds, often a mere Latin translation of their vernacular nickname, or long descriptive names of several words; probably no other single improvement in a method of nomenclature ever did so much to make the technique of nomenclature systematic. To couple the two terms at all was a great thing, the convenience of which we who never felt its want can hardly appreciate. To follow the generic by the specific term was itself of the same advantage that it is to have the Smiths and Browns of a directory entered under S and B, instead of by Johns and Jameses; besides according with the genius of the Romance languages, which commonly put the adjective after the noun. A Frenchman, for example, would say, *Bec-croisé aux ailes blanches de l'Amérique septentrionale*, or "Bill-crossed to the wings white of the America north," where we should say, "North American white-winged Crossbill," and Linnæus would have written *Loxia leucoptera.* The binomial scheme worked so well that it came to have the authority and force of a statute, which few subsequent naturalists have been inclined, and fewer have ventured, to violate; while it became an *ex post facto* law to prior naturalists, ruling them out of court altogether, as far as the legitimacy of any of the names they had bestowed was concerned. It necessarily rested, however, or at any rate proceeded upon, the false idea of a species as a fixity. Linnæus himself experienced the inadequacy of his system to deal

binomially with those lesser groups than species, commonly called "varieties," now better designated as "conspecies" or "subspecies"; and he often used a third word, separated however from the binomial name by intervention of the sign "var." or some other symbol. Thus, if he had supposed an American crossbill to be a variety of a European *Loxia leucoptera*, he might have called it *Loxia leucoptera, a, americana.* Some years ago, in treating of this subject, I urged the necessity of recognising by name a great number of forms of our birds intermediate between nominal species, and connecting the latter by links so perfect, that our handling of species required thorough reconsideration. The dilemma arose, through our very intimate knowledge of the climatic and geographical variation of species, either to discard a great number that had been described, and so ignore all the ultimate modifications of our bird-forms; or else to recognise as good species the same large number of forms that we knew shaded into each so completely that no specific character could be assigned. In the original edition of the *Key to North American Birds* (1872), I compromised the matter by reducing to the rank of varieties the nominal species that were known or believed to intergrade; and the original edition of my *Check List* (1873) distinguished such by the sign "var." intervening between the specific and the subspecific name. I subsequently determined to do away with the superfluous term "var.," and in the next edition of the *Check List* (1882) reverted to a purely trinomial system of naming the equivocal forms; as, *Loxia curvirostra americana.* This system is found to work well, and seems likely to come into general use.[1]

The Student cannot be too well assured that no such things as species, in the old sense of the word, exist in nature, any more than have genera or families an actual existence. Indeed they cannot be, if there is any truth in the principles discussed in our earlier paragraphs. Species are simply ulterior modifications, which once were, if they be not still, inseparably linked together; and their nominal recognition is a pure convention, like that of a genus. More practically hinges upon the way we regard them than turns upon our establishment of higher groups, simply because upon the way we decide in this case depends the scientific *labelling of specimens.* If we are speaking of a robin, we do not ordinarily concern ourselves with the family or order it belongs to, but we do require a

[1] Since the above was penned, the trinominal or trionymic system of nomenclature has been formulated and fully adopted by the committee on Nomenclature of the American Ornithologists' Union, of which Dr. Cones was chairman; and the decision of that body of nomenclatural legislators, as expressed in its Canons of Nomenclature, has been recognised as authoritative not only by American ornithologists in general, but by naturalists in other departments of zoology, notably mammalogy, herpetology, ichthyology, malacology, and entomology. The scheme has become well known to British ornithologists as a distinctive feature of the "American School."

technical name for constant use. That name is compounded of its genus, species, and variety. No infallible rule can be laid down for determining what shall be held to be a species, what a conspecies, subspecies, or variety. It is a matter of tact and experience, like the appreciation of the value of any other group in zoology. There is, however, a convention upon the subject, which the present workers in ornithology in America find available; and there is no better rule to go by. They treat as "specific" any form, however little different from the next, that is not known or believed to intergrade with that next one; between which and the next one no intermediate equivocal specimens are forthcoming, and none, consequently, are supposed to exist. This is to imply that the differentiation is accomplished, the links are lost, and the characters actually become "specific." They treat as "varietal" of each other any forms, however different in their extreme manifestation, which they know to intergrade, having the intermediate specimens before them, or which they believe with any good reason do intergrade. If the links still exist, the differentiation is still incomplete, and the characters are not specific, but only varietal, in the literal sense of these terms. In the latter case, the oldest name is retained as the specific one, and to it is appended the varietal designation: as, *Turdus migratorius propinquus.* The specific and subspecific words are preferably written with a small initial letter, even when derived from the name of a person or place, after the example of Dr. P. L. Sclater and other eminent British naturalists.

One other term than those just considered sometimes forms part of a bird's scientific name: this is the *subgenus.* When introduced, it always follows the generic term, in parentheses; thus, *Turdus (Merula) torquatus.* This is cumbrous, especially when there are already three terms, and is little used. I have latterly discarded it altogether. There is no difference in kind between a subgenus and a genus,—it is a difference of slight degree merely; and modern genera have so multiplied that one can easily find a single name for any generic refinement he may wish to indulge.

It has always been customary to write after the bird's name the name of the original describer of the species,—originally and properly, as the authority or voucher for the validity of the species named. But as genera multiplied, it was often found necessary to change the generic name, the species being placed in another genus than that to which its original namer referred it. The name of the person who originated the new combination came to be generally suffixed, presumably as the authority for the validity of the classification implied. As this was to ignore the proprietorship of the original describer, it became customary to retain that describer's name in parentheses and add that of the classifier; thus, *Turdus*

migratorius Linnæus; *Planesticus migratorius* (Linn.) Bonaparte. The practice still prevails.

It would take me too far to go fully into the rules of nomenclature: some few points may be noted. A proper sense of justice to the describers of new genera, species, and varieties prompts us to preserve inviolate the names they see fit to bestow, with certain salutary provisions. Hence arises the "law of priority." The *first* name given since 1758 is to be retained and used, if it can be identified with reasonable certitude; that is, if we think we know what the giver meant by it. But it is to be discarded, and the next name in priority of time substituted, if it is "glaringly false or of express absurdity,"—as calling an English bird "*africanus*," or a black one "*albus*." No generic name can be duplicated in zoology, and one once void for any reason cannot be revived and used in any connection. The same specific name cannot be used twice in the same genus.

The Actual Classification of Birds has undergone radical modification of late years, though the same machinery is employed for its expression. This is as would be expected, seeing how profoundly the theory of Evolution has affected our principles of classification, how completely the morphological has replaced other systems, and how steadily our knowledge of the structure of birds, and their chronological relations, has progressed. Nevertheless, the ornithological system is still in a transition state.

With this glance at some taxonomic principles and practices, I pass to an outline of the structure of birds, some knowledge of which is indispensable to any appreciation of ornithological definitions and descriptions. It is necessary to be brief, and I shall confine myself mainly to the consideration of those points, and the explanation of those technical terms, which the student needs to understand in order to use any systematic treatise easily and successfully.

§ 3.—DEFINITIONS AND DESCRIPTIONS OF THE EXTERIOR PARTS OF BIRDS

a. Of the Feathers, or Plumage

Feathers are possessed only by birds, and all birds possess them. Feathers are modified scales; like scales, hair, horns, plates, sheaths, etc., they are outgrowths of the integument, or skin covering the body, and therefore belong to the class of *epidermic* (Gr. ἐπί, *epi*, upon; δέρμα, *derma*, skin), or *exoskeletal* (Gr. ἐξ, *ex*, out; σκελ-όν, *skeleton*, dried; in the sense of "outer skeleton") structures.

The horny coverings of the beak and feet are of the same class, but very differently developed. Besides being the most highly developed or complexly specialised, wonderfully beautiful and perfect kind of tegumentary outgrowths—besides fulfilling in a singular manner the design of covering and protecting the body—feathers have their particular locomotory office: that of accomplishing the act of flying in a manner peculiar to birds. For all vertebrates, excepting birds, that progress through the air—the flying-fish, with its enlarged pectoral fins; the flying-reptile, with its skinny parachute; the flying mammal (bat) with its great webbed fingers—accomplish aërial locomotion by means of tegumentary *expansions*. Birds alone fly with tegumentary outgrowths, or appendages. All a bird's feathers, of whatever kind, collectively constitute its *ptilosis* (Gr. πτίλον, *ptilon*, a feather) or PLUMAGE (Lat. *pluma*, a plume).

Development of Feathers.—In a manner analogous to that of hair, a feather grows in a little pit or pouch formed by inversion of the dermal or true-skin layer of the integument, being formed in a closed follicle or shut sac consisting of an inner and outer coat separated by a layer of fine granular substance. The outer layer or outer follicle is composed of several thin strata of nucleated epithelial cells (cuticle cells); the inner is thicker, spongy, and filled with gelatinous fluid; a little artery and vein furnish the blood circulation, very active during the formation of feathers. The inner is the true *matrix* or mould upon which the feather is formed, evolving from the blood-supply the gelatinous material, and resolving this into cell-nuclei; the granular layer is the formative material which becomes the feather. The outer grows a little beyond the cutaneous sac that holds it, and opens at the end; from this orifice the future feather protrudes, sprouting as a little fine-rayed pencil point. The process is thus graphically illustrated by Huxley: "The integument of birds is always provided with horny appendages, which result from the conversion into horn of the cells of the outer layer of the epidermis. But the majority of these appendages, which are termed 'feathers,' do not take the form of mere plates developed upon the surface of the skin, but are evolved within sacs from the surfaces of conical papillæ of the dermis. The external surface of the dermal papilla, whence a feather is to be developed, is provided upon its dorsal [upper] surface with a median groove, which becomes shallower towards the apex of the papilla. From this median groove lateral furrows proceed at an open angle, and passing round upon the under surface of the papilla, become shallower, until, in the middle line, opposite the dorsal median groove, they become obsolete. Minor grooves run at right angles to the lateral furrows. Hence the surface of the papilla has the character of a kind of mould, and if it were repeatedly dipped in

such a substance as a solution of gelatine, and withdrawn to cool, until its whole surface was covered with an even coat of that substance, it is clear that the gelatinous coat would be thickest at the basal or anterior end of the median groove, at the median ends of the lateral furrows, and at those ends of the minor grooves which open into them; while it would be very thin at the apices of the median and lateral grooves, and between the ends of the minor grooves. If, therefore, the hollow cone of gelatine, removed from its mould, were stretched from within; or if its thinnest parts became weak by drying; it would tend to give way, along the inferior median line, opposite the rod-like cast of the dorsal median groove and between the ends of the casts of the lateral furrows, as well as between each of the minor grooves, and the hollow cone would expand into a flat, feather-like structure with a median shaft, as a 'vane' formed of 'barbs' and 'barbules.' In point of fact, in the development of a feather such a cast of the dermal papilla is formed, though not in gelatine, but in the horny epidermic layer developed upon the mould, and, as this is thrust outward, it opens out in the manner just described. After a certain period of growth the papilla of the feather ceases to be grooved, and a continuous horny cylinder is formed, which constitutes the 'quill.'" (Introd. *Classif. Anim.* p. 71.)

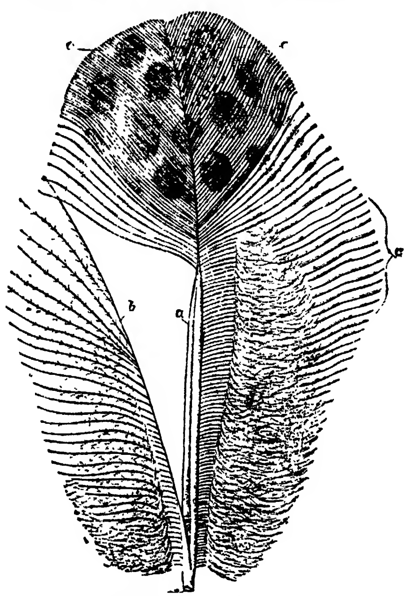


FIG. 19.—A partly pennaceous, partly plumulaceous feather from Argus pheasant; after Nitzsch. *ad*, main stem; *d*, calamus; *a*, rhachis; *c*, *c*, *c*, vanes, cut away on left side in order not to interfere with *b*, the after-shaft, the whole of the right vane of which is likewise cut away.

Structure of Feathers.—A perfect feather, possessing all the parts it can develop, consists of a main stem, shaft or scape (Lat. *scapus*, a stalk; Fig. 19, *ad*), and a supplementary stem or after-shaft (*hyporhachis*; Gr. ὑπό, *hupo*, under, ῥάχις, *rhachis*, a spine or ridge; Fig. 19, *b*), each bearing two webs or vanes (Lat. *vexillum*, pl. *vexilla*, a banner; Fig. 19, *c*, *c*, *c*), one on either side. The whole scape is divided into two parts: one, nearest the body of the bird, the tube or barrel or "quill" proper (Lat. *calamus*, a reed), which is a hard, horny, hollow, and semi-transparent cylinder, containing a little pith

in the interior; it bears no webs. One end of this quill tapers to be inserted into the skin; the other passes, at a point marked by a little pit (Lat. *umbilicus*, the navel) into the shaft proper or *rhachis*, the second part of the stem. The *rhachis* is a four-sided prism, squarish in transverse section, and tapers gradually to a fine point; it is less horny than the barrel, very elastic, opaque, and pithy; it bears the vexilla. The after-shaft, when well developed, is like a duplicate in miniature of the main feather, from the stem of which it springs, at junction of calamus with rhachis, close by the umbilicus. It is generally very small compared with the main part of the feather, though quite as large in a few kinds of birds; it is entirely wanting in some groups of birds; it is never developed on the large, strong wing- and tail-feathers. The *vane* consists of a series of appressed, flat, narrowly linear or lance-linear laminæ or plates, set obliquely on the rhachis by their bases, diverging out from it at a varying open angle, ending in a free point; each such narrow, acute plate is called a *barb* (Lat. *barba*, a beard; Fig. 20, *a*, *a*). Now if these laminæ or barbs simply lay alongside one another, like the leaves of a book, the feather would have no consistency; therefore, they are connected together; for, just as the rhachis bears its vane or series of barbs, so does each barb bear its vanes of the second order, or little vanes, called *barbules* (dimin. of *barba*; Fig. 20, *b*, *b*, *c*). These are to the barbs exactly what the barbs are to the shaft, and are similarly given off from both sides of the upper edges of the barbs; they make the vane truly a *web*, that is, they so connect the barbs together that some little force is required to pull them apart. Barbules are variously shaped, but generally flat sideways, with upper and lower border at base, rapidly tapering to a slender thready end, and are long enough to reach over several barbules of the next barb, crossing the latter obliquely. All the foregoing structures are seen by the naked eye or with a simple pocket lens, but the next to be described require a microscope: they are the *barbicels* (another dimin. of *barba*), also called *cilia*, or lashes (Fig. 21); and *hamuli*, or hooklets (Lat. *hamulus*, a little hook; Fig. 21). These are simply a sort of fringe to the barb-

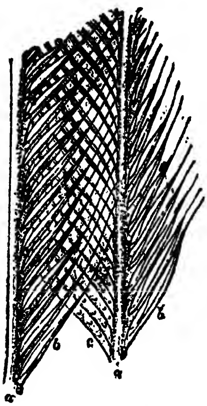


FIG. 20.—Two barbs, *a*, *a*, of a vane, bearing anterior, *b*, *b*, and posterior, *c*, barbules; enlarged; after Nitzsch.

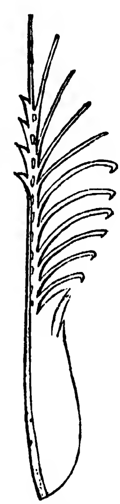


FIG. 21.—A single barbule, bearing barbicels and hooklets; magnified; after Nitzsch.

ules, just as if the lower edge of the barbules were frayed out, and only differ from each other in that barbicels are plain hair-like processes, while hamuli are hooked at the end; they are not found on all feathers, nor on all parts of some feathers. Barbicels occur on both anterior and posterior rows of barbules, though rarely on the latter; hooklets are confined to any anterior series of barbules, which, as we have seen, overlie the posterior rows, forming a diagonal mesh-work. The design of this beautiful structure is evident; the barbules are interlocked, and the whole made a web; for each hooklet of one barbule catches hold of a barbule from the next barb in front, any barbule thus holding on to as many of the barbules of the next barb as it has hooklets; while, to facilitate this interlocking, the barbules have a thickened upper edge of the right size for the hooklets to grasp. The arrangement is shown in Fig. 22, where *a*, *a*, *a*, *a*, are four barbs in transverse section, viewed from the cut surfaces, with their anterior, *b*, *b*, *b*, *b*, and posterior, *c*, *c*, *c*, *c*, barbules, the former bearing the hooklets which catch over the edge of the latter.

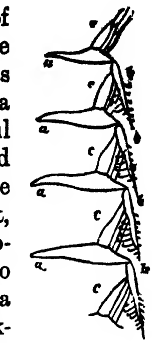


FIG. 22.—Four barbs in cross section, *a*, *a*, *a*, *a*, bearing anterior, *b*, *b*, *b*, *b*, and posterior, *c*, *c*, *c*, *c*, barbules, the former bearing hooklets which catch over the latter; magnified; after Nitzsch.

Types of Feathery Structure.—But all feathers do not answer the above description. The after-shaft may be wanting. Hooklets may not be developed, as frequently happens. Barbicels may be few or entirely wanting. Barbules may be similarly deficient, or so defective as to be only recognised by their position and relations. Even barbs themselves may be few or lacking on one side of the shaft, or on both sides, as in certain bristly or hair-like styles of feathers. Consideration of these and other modifications of feather-

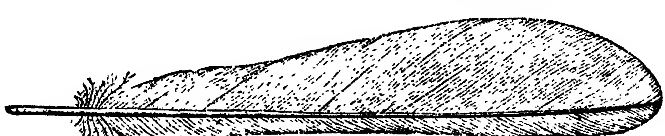


FIG. 23.—A feather from the tail of a kingbird, *Tyrannus carolinensis*, almost entirely pennaceous; no after-shaft. From nature, by Coues.

structure has led me to the recognition of *three* types or plans: 1. The perfectly feathery, *plumous*, or *pennaceous* (Lat. *pluma*, a plume, or *penna*, a feather fit for writing with; Fig. 23), as above described. 2. The downy or *plumulaceous* (Lat. *plumula*, a little plume, a down-feather), when the stem is short and weak, with soft rhachis and barbs, with long slender thready barbules, little knotty dilatations in

place of barbicels, and no hooklets. 3. The hairy, bristly, or *filoplumaceous* (Lat. *filum*, a thread), with a very long, slender stem, and rudimentary or very small vanes composed of fine cylindrical barbs and barbules, if any, and no barbicels, knots, or hooklets. There is no abrupt definition between these types of structure ; in fact, the same feather may be constructed on more than one of these plans, as in Fig. 19, which is partly pennaceous, partly plumulaceous. All feathers are built upon one or another, or some combination, or modification, of these types ; and, in all their endless diversity, may be reduced to four or five

Different Kinds of Feathers.—1. *Contour-feathers*, *pennæ* or *plumæ* proper, have a perfect stem composed of calamus and rhachis, with vanes of pennaceous structure, at least in part, usually plumulaceous toward the base. These form the great bulk of the surface-plumage exposed to light; their beautiful tints give the bird's colours; they are the most modified in detail of all, from the fish-like scales of a penguin's wings to the glittering jewels of the humming-bird, and the endless array of the tufts, crests, ruffs, and other ornaments of the feathered tribes; even the imperfect bristle-like feathers above mentioned may belong among them. Another feature is, that they are usually individually moved by subcutaneous muscles, of which there may be several to one feather, passing to be attached to the sheath of the tube, inside the skin, in which the stem is inserted. These muscles may be plainly seen under the skin of a goose, and every one has observed their operation when a hen shakes herself after a sand-bath, or any bird erects its top-knot. 2. *Down-feathers*, *plumulæ*, are characterised by a downy structure throughout. They more or less completely invest the body, but are almost always hidden beneath the contour-feathers, like padding about the bases of the latter ; occasionally they come to light, as in the fleecy ruff about the neck of the condor, and then usually replace contour-feathers ; they have an after-shaft, or none ; and sometimes no rhachis at all, the barbs then being sessile in a tuft at the end of the quill. They often stand in a regular quincunx (⁚·⁚) between four contour-feathers. 3. *Semiplumes*, *semiplumæ*, may be said to unite the characters of the last two, possessing the pennaceous stem of the former, and the plumulaceous vanes of the latter; they are with or without after-shaft. They stand among pennæ, as the plumulæ do, about the edges of patches of the former, or in parcels by themselves, but are always covered by contour-feathers. 4. *Filoplumes*, *filoplumæ*, or thread-feathers, have an extremely slender, almost invisible stem, not well distinguished into barrel and shaft, and usually no vane, unless a terminal tuft of barbs may be held for such. Long as they are, they are usually hidden by the contour-feathers, close to which they stand as access-

ories, one or more seeming to issue out of the very sacs in which the larger feathers are implanted. These are the nearest approach to hairs that birds have; they are very well shown on domestic poultry, being what a good cook finds it necessary to singe off after plucking a fowl for the table. 5. Certain down-feathers are remarkable for continuing to grow indefinitely, and with this unlimited growth is associated a continual breaking down of the ends of the barbs. Such plumulæ, from being always dusted over with dry, scurfy exfoliation, are called *powder-down;* they may be entitled to rank as a fifth kind. I call them *pulviplumes.* They occur in the hawk, parrot, and gallinaceous tribes, and especially in the herons and their allies. They are always present in the latter, where they may be readily seen as at least two large patches of greasy or dusty, whitish feathers, matted over the hips and on the breast.

Feather Oil Gland.—Birds do not perspire, and cutaneous glands, corresponding to the sweat-glands and sebaceous follicles so common in *Mammalia*, are little known among them. But their "oil-can" is a kind of sebaceous follicle, which may be noticed here in connection with other tegumentary appendages. This is a two-lobed or rather heart-shaped gland, saddled upon the "pope's-nose," at the root of the tail, and hence sometimes called the *uropygial gland* (Lat. *uropygium*, rump), or rump-gland. I have named it the *elæodochon* (Gr. ἐλαιοδόχος, *elaiodochos*, containing oil; Fig. 24, 9). It is composed of numerous slender tubes or follicles which secrete the greasy fluid, the ducts of which, uniting successively in larger tubes, finally open by one or more pores, commonly upon a little nipple-like elevation. Birds press out a drop of oil with the beak and dress the feathers with it, in the well-known operation called "preening." The gland is large and always present in aquatic birds, which have need of waterproof plumage; smaller in land-birds, as a rule, and wanting in some. The presence or absence of this singular structure, and whether or not it is surmounted by a particular circlet of feathers, distinguishes certain groups of birds, and has come to be much used in classification.

Pterylography.—Feathered Tracts and Unfeathered Spaces.—Excepting certain birds having obviously naked spaces, as about the head or feet, all would be taken to be fully feathered. So they are *covered with feathers*, but it does not follow that feathers are everywhere implanted upon the skin. On the contrary, a uniform and continuous *pterylosis* is the rarest of all kinds of feathering; though such occurs, almost or quite perfectly, among certain birds, as the ostrich tribe, penguins, and toucans. If we compare a bird's skin to a well-kept park, part woodland, part lawn; then where feathers grow is the woodland, where they do not grow is the lawn. The former places are called *tracts* or *pterylæ* (Gr. πτερόν, *pteron*, a plume

and ὕλη, *hylē*, a wood); the latter, *spaces* or *apteria* (Gr. α privative, and πτερόν); they mutually distinguish certain definite areas. Not only are the *pterylæ* and *apteria* thus definite, but their size, form, and arrangement mark whole families and even orders of birds; so that *pterylosis*, or the formation of the feather-tracts, becomes available, and is indeed found to be important, for purposes of classification. *Pterylography*, or the description of this matter, has been made a special study by the celebrated Nitzsch, who has laid down the general plan of pterylosis which obtains in the great majority of birds, as follows: 1. The spinal or dorsal tract (*pteryla spinalis;* Fig. 24, 1), running along the middle of the bird above from the nape of the neck to the tail; subject to great variation in width, to dilation and contraction, to forking, to sending out branches, to interruption, etc. 2. The humeral tracts (*pt. humeralis;* Lat. *humerus*,

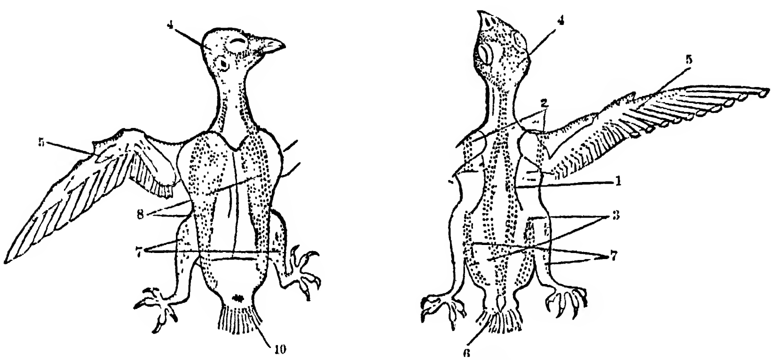


FIG. 24.—Pterylosis of *Cypselus apus*, drawn by Coues after Nitzsch; right hand upper, left hand lower, surface. 1, spinal tract; 2, humeral; 3, femoral; 4, capital; 5, alar; 6, caudal; 7, crural; 8, ventral; 9, elæodochon; 10, anus.

the shoulder, or upper-arm bone; Fig. 24, 2), always present, one on each wing; they are narrow bands, running from the shoulder obliquely backward upon the upper-arm bone, parallel with the shoulder-blade. 3. The femoral tracts (*pt. femorales;* Lat. *femur*, the thigh; Fig. 24, 3): a similar oblique band upon the outside of each thigh, but subject to great variation. 4. The ventral tract (*pt. ventralis;* Lat. *venter*, the belly; Fig. 24, 8), which forms most of the plumage on the under part of a bird, commencing at or near the throat, and continued to the vent; like the dorsal tract, it is very variable, is usually bifurcate, or forked into right or left halves, with a median apterium, is broad or narrow, branched, etc.; thus, Nitzsch enumerates seventeen distinct modifications. The foregoing are mostly isolated tracts, that is, bands nearly surrounded by complementary apteria; the following are, in general, continuously and uniformly feathered, and thus practically equivalent to

the part of the body they represent: Thus, 5, the head tract (*pt. capitalis;* Lat. *caput*, *capitis*, head; Fig. 24, 4) clothes the head, and generally runs into the beginning of both dorsal and ventral tracts. 6. The wing tract (*pt. alaris;* Lat. *ala*, wing; Fig. 24, 5) represents all the feathers that grow upon the wing, excepting those of the humeral tract. 7. The tail tract (*pt. caudalis;* Lat. *cauda*, tail; Fig. 24, 6) includes the tail-feathers proper and their coverts, and those about the elæodochon, and usually receives the termination of the dorsal, ventral, and femoral tracts. 8. The leg tract (*pt. cruralis;* Lat. *crus*, *cruris*, leg; Fig. 24, 7) clothes the legs as far as these are feathered, which is generally to the heel, always below the knee, and sometimes to the toes or even the claws.—I need not enumerate the *apteria*, as these are merely the complements of the pterylæ. The highly important special "flight-feathers" of the wings and "rudder-feathers" of the tail are to be examined beyond, in describing those members.

Endysis and Ecdysis.—Putting on and off Plumage.—Newly hatched birds are covered for some time with a kind of down, entirely different from such feathers as they ultimately acquire. It is scanty, leaving much or all of the body naked, in most *altricial* birds, such as are reared by the parents in the nest (Lat. *altrix*, female nourisher); but thick and puffy in some *Altrices*, and in all *Præcoces* (Lat. *præcox*, precocious) which run about at birth. Since many birds which require to be reared in the nest are also hatched clothed, or very speedily become downy, a more exact distinction may be drawn by using the terms *ptilopædic* and *psilopædic* (Gr. πτίλον, *ptilon*, a feather; ψιλός, *psilos*, bare; and παῖς, *pais*, a child) respectively for those birds which are hatched feathered or naked —a chicken and a canary-bird are familiar examples. It is the rule that the higher birds are born helpless and naked, requiring to be reared in the nest till their feathers grow; the reverse with lower birds, as the walking, wading, and swimming kinds. It offers, however, many exceptions; thus, no birds are more naked and helpless at birth than young cormorants. Probably all præcocial birds are also ptilopædic, and all psilopædic birds altricial; but the converse is far from holding good, many *Altrices*, as hawks and owls, being also ptilopædic. In other words, psilopædic birds are always altricial, but ptilopædic birds may be either altricial or præcocial. In any case, true feathers are soon gained, in some days or weeks—those of the wings and tail being usually the first to sprout. The acquisition of plumage is called *endysis* (Gr. ἔνδυσις, *endusis*, putting on). The renewal of plumage is a process familiar to all, in its generalities, under the term "moult," or *ecdysis* (Gr. ἔκδυσις, *ekdusis*, putting off). Feathers are of such rapid growth, and make such a drain upon the vital energies, that we easily understand how

critical are periods of the change. The first plumage is usually worn but a short time; then another more or less complete change commonly occurs. The moult is as a rule annual; and in many cases more than one moult is required before the bird attains the perfection of maturity in its feathering. It is well known how different many birds are the first year in their coloration from that afterward acquired. Sometimes changes progress for several years; and some birds appear to have a period of senile decline. All such changes are necessarily connected, if not with actual moult, as is the rule, then at any rate with wear and tear and repair of the plumage. The first plumage being gained, under whatever conditions peculiar to the species, it is the general rule that birds are subject to *single* or *annual* moult. This commonly occurs in the fall, when the duties of incubation are concluded, and the well-worn plumage most needs renewal. Many, however, moult twice a year, the additional moult usually occurring in the spring-time, when a fresh nuptial suit is acquired; in such cases the moult is said to be *double* or *semi-annual.* Such additional moult is generally incomplete; that is, all the feathers are not shed and renewed, but more or fewer new ones are gained, with more or less loss of the old ones, if any. The most striking ornaments donned for the breeding season, as the elegant plumes of many herons, are usually worn but a brief time, being doffed in advance of the general fall moult. A few birds, as the ptarmigan (*Lagopus*), regularly have even a third or *triple* moult, shedding many of their feathers as usual in the early autumn, then changing entirely to pure white for the winter, then in spring moulting completely to assume their wedding-dress. As a rule, feathers are moulted so gradually, particularly those of the wings and tail, and so simultaneously upon right and left sides of the body, that birds are at no time deprived of the power of flight. The first *flight-feathers* acquired by young birds are usually kept till the next season; but in those that fly very early, before they are half-grown, as so many gallinaceous birds do, their first weak wing-feathers are included in the general moult which occurs to young and old in the fall. The duck tribe offer the remarkable case that they drop their wing-quills so nearly all at once as to be for some time deprived of the power of flight. It is quite certain that many birds change the colours of their plumage remarkably, without losing or gaining any feathers, by some process which affects the texture of the feathers, such as the shedding of the barbicels and hooklets, or its pigmentation, or by such processes combined. The male bobolink (*Dolichonyx oryzivorus*) changes from the buff dress of the female to his rich black suit without losing or gaining any feathers, a process which is called *aptosochromatism.* It is difficult to lay down any rules of moulting

for particular groups of birds, since birds very closely related differ greatly in respect to their changes of plumage; and the subject has not yet received the attention its interest and importance should claim for it. The physiological processes involved are analogous to those concerned in the shedding of the hair of mammals and the casting of the cuticle of reptiles.

Plumage-changes with Sex, Age, and Season.—Aside from any consideration of the way in which plumage changes, whether by moult or otherwise, the fact remains that most birds of the same species differ more or less from one another according to certain circumstances. The dissimilarity is not only in coloration, though this is the usual and most pronounced difference, but also in the degree of the development of plumes—their size, form, and texture. Since young birds are those which have not come to sexual vigour; since breeding recurs at regular periods of the year; and since males and females usually differ in plumage, nearly all the various dresses worn by different individuals of the same species are correlated with the conditions of the reproductive system. As the internal generative organs represent of course the essential or *primary* sexual characters, all those features of the plumage just indicated may be properly classed as *secondary sexual characters*. These are of great importance, not only in practical ornithology, but as the basis of some of the soundest views that have been advanced respecting the evolution of specific characters in this class of animals. The generalisations may be made: that when the sexes are strikingly different in plumage, the young at first resemble the female; when the adults are alike, the young are different from either; when seasonal changes are great, the young resemble the fall plumage of the parents; and further, that when the adults of two related species of the same genus are nearly alike, the young are usually intermediate, their specific characters not being fully developed. Specific characters are often to be found only in the male, the females of two related species being scarcely distinguishable, though the males may be told apart at a glance. Extraordinary developments of feathers, as to size, shape, and colour, are often confined to one sex, usually the male. The more richly, extensively, or peculiarly the male is adorned, the simpler the female in comparison, as the peacock and peahen. Darwin has formulated the several categories of secondary sexual characters, giving the following rules or classes of cases: "1. When the adult male is more beautiful or conspicuous than the adult female, the young of both sexes in their first plumage closely resemble the adult female, as with the common fowl and peacock, or, as occasionally occurs, they resemble her much more closely than they do the adult male. 2. When the adult female is more conspicuous than the adult male,

as sometimes, though rarely, occurs [chiefly with certain birds of prey and snipe-like birds], the young of both sexes in their first plumage resemble the adult male. 3. When the adult male resembles the adult female, the young of both sexes have a peculiar first plumage of their own, as with the robin [usual]. 4. When the adult male resembles the adult female, the young of both sexes in their first plumage resemble the adults [unusual]. 5. When the adults of both sexes have a distinct winter and summer plumage, whether or not the male differs from the female, the young resemble the adults of both sexes in their winter dress, or much more rarely in their summer dress, or they resemble the females alone. Or the young may have an intermediate character; or again, they may differ greatly from the adults in both their seasonal plumages. 6. In some few cases the young in their first plumage differ from each other according to sex; the young males resembling more or less closely the adult males, and the young females more or less closely the adult females."—(*Desc. of Man*, ed. 1881, p. 466.)

b. The Topography of Birds.

The Contour of a Bird with the feathers on is spindle-shaped or *fusiform* (Lat. *fusus*, a spindle), tapering at both ends; it represents two cones joined base to base at the middle or greatest girth of the body, tapering in front to the tip of the bill, behind to the end of the tail. The obvious design is easiest cleavage of air in front, and least drag or wash behind, in the act of flying. This shape is largely produced by the lay of the plumage; a naked bird presents several prominences and depressions, this irregular contour being reducible, in general terms, to two spindles or double cones. The head tapers to a point in front, at the tip of the bill, and contracts behind, toward the middle of the neck, in consequence of diminution in bulk of the muscles by which it is slung on the neck; which last is somewhat contracted or hour-glass-shaped near the middle, swelling where it is slung to the body. The body is largest in front and tapers to the tail. The

Centre of Gravity is admirably preserved beneath the centre of the body, and opposite the points where it is supported by the wings. The enormous breast-muscles of a bird are among its heaviest parts, sometimes weighing, to speak roundly, as much as one-sixth of the whole bird. Now these are they that effect all the movements of the wings at the shoulder-joints, lifting as well as lowering the wings. Did these pectoral muscles pull straight, the lifters of the wing would have to be *above* the shoulder-joint; but they all lie below it, and the lifters accomplish their office by running through pulleys to change the line of their traction. They

work like men hoisting sails from the deck of a vessel; and thus, like a ship's cargo, a bird's chief weight is kept below the centre of motion. Top-heaviness is further obviated by the way in which birds with a long heavy neck and head draw these parts in upon the breast, and extend the legs behind, as is well shown by the attitude of a heron flying. The nice adjustment of balance by the variable extension of the head and feet is exactly like that produced in weighing by shifting a weight along the arm of a steelyard; and together with the slinging of the chief weight under the wings instead of over or even between them, enables a bird to easily keep right side up in flight. The

Exterior of a Bird is divided for purposes of description into *seven* parts:—1. The head (Lat. *caput*); 2. The neck (Lat. *collum*); 3. The body proper, or trunk (Lat. *truncus*); 4. The bill or beak (Lat. *rostrum*); 5. The wings (Lat. pl. *alæ*); 6. The tail (Lat. *cauda*); 7. The feet (Lat. pl. *pedes*). Of these, 1, 2, 3, the head, neck, and trunk, are collectively termed the *body* (Lat. *corpus*), in distinction from 4, 5, 6, 7, which are the *members* (Lat. pl. *membra*). The wings and feet are of course double or paired parts. The bill is strictly but a part of the head; but its manifold uses as an organ of prehension make it functionally a hand, and therefore one of the "members." The

Head has the general shape of a four-sided pyramid; of which the base is applied to the end of the neck, therefore not appearing from the exterior, and the apex of which is frustrated at the base of the bill. The uppermost side is more or less convex or vaulted, sloping in every direction; the under side is flattish and horizontal; the lateral surfaces are flattish and vertical; all similarly taper forward. The departures from any such typical shape are endless in degree and variable in kind, giving rise to numerous general descriptive terms, such as "head flattened," "head globular," but not susceptible of exact definition. The head is moulded, of course, upon the skull, corresponding in a general way to the brain-cavity of the cranium proper, both in size and shape; but it differs in several particulars. In the first place, there is the scaffolding of the jaws; secondly, large excavations to receive the eyeballs, and smaller ones for the ear-parts; thirdly, muscular masses overlying the bone; and lastly, in some birds, large hollow spaces in the bone between the inner and outer tables or plates of the cranial walls. Each side of the head presents two openings for the *eye* (Lat. *oculus*) and *ear* (Lat. *auris*), the position of which is variable, both absolutely and in relation to each other. But in the vast majority of birds, the eye is strictly lateral in situation, and near the middle of the side of the head; while the ear is behind and a little below the eye, near the articulation of the lower jaw. But the shape of the

skull of owls is such, that the eyes are directed forward, and such birds are said to have "eyes anterior." Owls also have enormous outer ears, in some cases provided with a movable flap or conch, closing upon the opening like the lid of a box; in many cases the ear-parts, and some of the cranium itself, being unsymmetrical. In most birds the ear-opening is quite small, and only covered by modified feathers, the ear-coverts or *auriculars*. In the woodcock and snipe, owing to the way the brain-box is tilted up, the ears are below and not behind the eyes. The *mouth* (Lat. *os*, gen. *oris*) is always a fissure across the front of the head. The cleavage varies, both in extent and direction; the latter is usually horizontal, or nearly so, but may trend much downward; the former varies from a minimum, in which the cleft does not reach back of the horny part of the bill, as in a snipe, to the maximum seen in fissure-billed birds like the swifts and goatsuckers, which gape almost from ear to ear. There are no other openings in the head proper, for the nostrils are always in the bill. The

Neck, in effect, is a simple cylinder, rendered somewhat hour-glass-shaped, as above said. It consists of a movable chain of bones, the *cervical vertebræ* (Lat. *cervix,* the neck; *verto,* I turn) enveloped in muscle, along which in front lie the gullet (Lat. *œsophagus*) and windpipe (Lat. *trachea*), with associate blood-vessels, nerves, etc. Its length is very variable, as is the number of its bones, the latter ranging from 8 to about 26. Bearing as it does the head, with the *bill*, which is the true *hand* of a bird, the neck is extremely flexible, to permit the necessarily varied movements of this handy member. Its least length may be said to be that which allows the point of a bird's beak to reach the oil-gland on the rump; its greatest length sometimes exceeds that of the body and tail together, as in the case of a swan, crane, or heron. The length is usually in direct proportion to that of the legs, in obvious design of allowing the beak to touch the ground easily to pick up food. The neck is habitually carried in a double curve, like an open S or italic *f*, the lower belly of the curve, convex forward, fitting in between the forks of the merrythought (Lat. *furculum*), the upper curve holding the head horizontal at the same time. This "sigmoid flexure" (*sigma*, Greek S), highly characteristic of the bird's neck, is produced by the saddle-shaping of the articular surfaces of the several bones. The mechanical arrangement is such, that the sigma may be easily bent till the upper end (head) rests on the lower convexity, or as easily straightened to a right line; but little if any further deviation in opposite curvature is permitted. As a generalisation, the neck may be called relatively longest in wading birds, as herons, cranes, ibises, etc.; shortest in perching birds, as the great majority of small *Passeres*; intermediate in

swimming birds. But many swimmers, as swans and cormorants, have extremely long necks; and some waders, as plovers, have very short ones. A long neck is a rarity among the higher birds (above the *Gallinæ*), in most of which the head seems to nestle upon the shoulders. The longer the neck, the more sinuous and flexible is it likely to be. Anatomically, the neck ends in front at the articulation of the *atlas* (first cervical vertebra) with the skull, and behind at the first vertebra which bears free jointed ribs reaching the sternum. (See also § 4, *Anatomy*.) The shape of the

Body proper, or Trunk, is obviously referable to that of the egg; it is *ovate* (Lat. *ovum*, an egg; whence *oval*, the plane figure represented by the middle lengthwise section of an egg; *ovate* or *ovoid*, the solid figure). The swelling of the breast represents the greatest diameter of the egg, usually near the larger end. But the ovoid is never perfectly expressed, and departures from the figure are numberless. In general, the higher perching birds have the body nearly of the ovate shape; among waders, the figure is usually *compressed*, or flattened vertically, as is well seen in the herons, and still better in the rails, where the lateral narrowing is at an extreme; among swimmers, the body is always more or less *depressed*, or flattened horizontally, and especially underneath, that the birds may rest on the water with more stability, as well shown by a duck or diver. Anatomically the body begins with the foremost *dorsal* or *thoracic vertebræ*, or those that bear true ribs; laterally, it ceases quite definitely at the shoulder-joints, the whole of the fore limb being outside the general content of the trunk; behind, in the middle line, it includes everything, only the tail-*feathers* themselves being beyond it; behind and laterally, it includes more or less of the legs, for these are generally buried in the common integument of the body to the knee-joint, nearly or quite so, and sometimes to the heel-joint; though in anatomical strictness the trunk should be limited by the hip-joint. The rib-bearing part of the back-bone, the ribs themselves, and the greatly enlarged breast-bone (Lat. *sternum*) compose the walls of the chest (Lat. *thorax*). Upon this bony box, which contains the heart and lungs and some other viscera, are saddled on each side the bones of the *shoulder-girdle* or *scapular arch*, namely, the shoulder-blades (Lat. *scapulæ*), the *coracoids*, and the collar-bones (Lat. *claviculæ*), all three of which, on each side, come together at the shoulder-joint (Figs. 1, 2). The thoracic cavity is not separated by any partition or *diaphragm* from that of the belly (Lat. *abdomen*), which with the *pelvis*, or basin, contains the digestive, urinary, and genital organs. The pelvis is composed, in dorsal mid-line, of so many of the vertebræ (*dorso-lumbar*, *sacral* proper, and *urosacral*), as become immovably joined to one another, and laterally of the confluent haunch-bones. The numerous *anchylosed*

(or confluent) vertebræ compose the *sacrum*. The haunch-bones or *ossa innominata* consist on each side of three bones, *ilium*, *ischium*, and *pubis*, in adult life more or less perfectly anchylosed. Where they all three come together is the hip-joint. The remaining bones, usually included among those of the body proper, are the *coccygeal* or caudal vertebræ. (For anatomical details see beyond, under *Osteology*, etc.)

Topography of the Body.—Besides being thus divided into head, neck, trunk, and members, the exterior of the body is further subdivided or mapped out into *regions* for the purposes of description. It is necessary for the student to become familiar with the "topography" of a bird, as this kind of mapping out may be called, for the names of the regions or outer areas are incessantly used in ordinary descriptive ornithology. Many more names have been applied than are in common use; I shall try to define and explain all those which are usually employed, beginning with the parts of the *body*, and ending with those of the *members*.

1. *Regions of the Body.*

Upper and Under Parts.—Draw a line from the corner of the mouth along the side of the head and neck to and through the shoulder-joint and thence along the side of the body to the root of the tail; all above this line, including the upper surfaces of the wings and tail, are *upper parts;* all below it, including under surfaces of wings and tail, are *under parts;* for which the short words "above" and "below" often stand. The distinction is purely arbitrary, but so convenient as to be practically indispensable. It will be seen how an otherwise lengthy description, enumerating parts that lie over or under the "lateral line," can be put in so few words as, for example, "above, green; below, yellow." Many birds' colours have some such simple general distribution. These parts are also the *dorsal* (Lat. *dorsum*, back) and *ventral* (Lat. *venter*, belly) surfaces or aspects. The upper parts of the body proper, or trunk, have also received the general name of *notæum* (Gr. νῶτος, *notos*, back); the under parts, similarly restricted, that of *gastræum* (Gr. γαστήρ, *gaster*, belly): but these terms are not much used. These two are *never naked*, while both head and neck may be variously bare of feathers. The only exception is the transient condition of certain birds during incubation, when, like the eider-duck, they pull off feathers to furnish the nest, or when the plumage, as usually happens, wears off. The gastræum is rarely ornamented with feathers different in texture or structure from those of the plumage at large; but such a case is furnished by Lewis's woodpecker (*Asyndesmus torquatus*). The notæum, on the contrary, is often the seat of extraordinary development of

feathers, either in size, shape, or texture, or all three of these qualities; as the singularly elegant dorsal plumes of many herons. Individual feathers of the notæum are generally pennaceous, and for the most part straight and lanceolate; and as a whole lie smoothly shingled or *imbricated*. The ventral feathers are usually more largely plumulaceous, and less flat and imbricated, but even

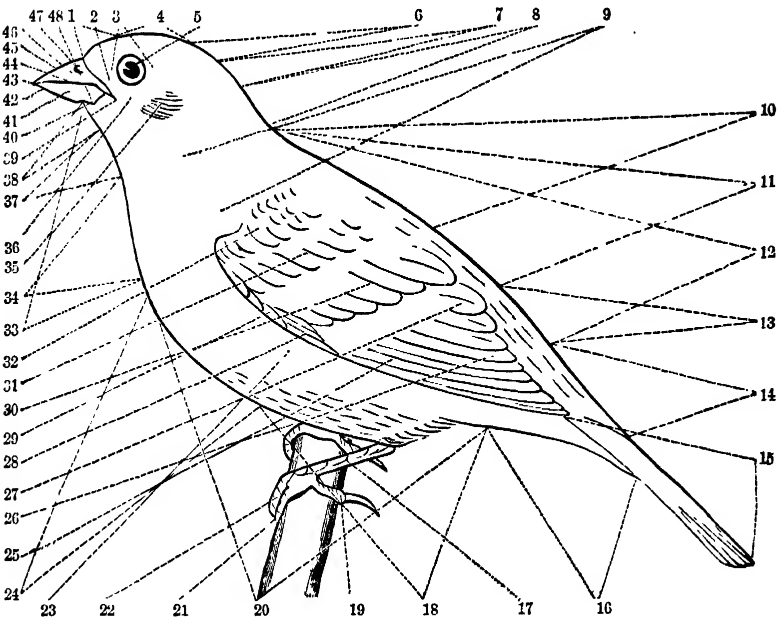


FIG. 25.—Topography of a Bird. 1, forehead (*frons*). 2, lore. 3, circumocular region. 4, crown (*vertex*). 5, eye. 6, hind head (*occiput*). 7, nape (*nucha*). 8, hind neck (*cervix*). 9, side of neck. 10, interscapular region. 11, *dorsum*, or back proper, including 10. 12, *notæum*, or upper part of body proper, including 10, 11, and 13. 13, rump (*uropygium*). 14, upper tail-coverts. 15, tail. 16, under tail-coverts (*crissum*). 17, tarsus. 18, abdomen. 19, hind toe (*hallux*). 20, *gastræum*, including 18 and 24. 21, outer or fourth toe. 22, middle or third toe. 23, side of the body. 24, breast (*pectus*). 25, primaries. 26, secondaries. 27, tertiaries; Nos. 25, 26, 27 are all *remiges*. 28, primary coverts. 29, *alula*, or bastard wing. 30, greater coverts. 31, median coverts. 32, lesser coverts. 33, the "throat," including 34, 37, 38. 34, *jugulum* or lower throat. 35, auriculars. 36, malar region. 37, *gula*, or middle throat. 38, *mentum*, or chin. 39, angle of commissure, or corner of mouth. 40, ramus of under mandible. 41, side of under mandible. 42, *gonys*. 43, *apex*, or tip of bill. 44, *tomia*, or cutting edges of the bill. 45, *culmen*, or ridge of upper mandible, corresponding to gonys. 46, side of upper mandible. 47, nostril. 48 passes across the bill a little in front of its *base*.

more compact, that is, thicker, than those of the upper parts; especially among water birds, where they are more or less curly, and very thick-set. There are subdivisions of the

Notæum.—Beginning where the neck ends, and ending where the tail-coverts begin (see Fig. 25, 12), this part of a bird is subdivided into *back* (Lat. *dorsum;* Fig. 25, 11) and *rump* (Lat. *uropygium;* Fig. 25, 13). These are in direct continuation of each other,

and their limits are not precisely defined; the feathers of both are of the *pteryla dorsalis.* In general, we should call the anterior two-thirds or three-fourths of notæum "back," and the rest "rump." With the former are generally included the scapular or shoulder-feathers, *scapulars* or *scapularies;* these are they that grow on the *pterylæ humerales.* The region of notæum they represent is called the *scapulare*, and that part of notæum strictly between them is called the *interscapulare* (Fig. 25, 10); it is often marked, as in the house sparrow, with streaks or some other distinctive coloration. A part of dorsum, lying between interscapulare and uropygium, is sometimes recognised as the "lower back" (Lat. *tergum*); but this distinction is not practically useful. To uropygium probably also belong the feathers of the *pterylæ femorales*, or at any rate these are commonly included with the rump in descriptions; but they more properly represent the *flanks* (Lat. *ilia*, or *hypochondria*); that is, sides of the rump. They are sometimes the seat of largely developed or otherwise peculiarly modified feathers, as the snowy flank-plumes of the white-bellied swift (*Panyptila saxatilis*) or violet-green swallow (*Tachycineta thalassina*), which meet over the rump. The whole of notæum, taken together with the upper surfaces of the wings, is called the *mantle* (Lat. *stragulum*, a cloak); often a convenient term, as, for example, in describing gulls and terns. In like manner, the

Gastræum is subdivided into regions, called, in general terms, *breast* (Lat. *pectus;* Fig. 25, 24), *belly* (Lat. *abdomen;* Fig. 25, 18), and *sides of the body* (Lat. *pleuræ;* Fig. 25, 23). The "sides" or pleuræ belong really as much to the dorsal as to the ventral aspects of a bird's body; but in consequence of the underneath-freighted shape, the line we drew passes so high up along them, that they are almost entirely given over to gastræum. The *breast* begins over the merrythought where jugulum (see beyond) ends; on either hand, it slopes up to "sides"; behind, its extension is indefinite. It should properly reach as far as the breast-bone does, to the limit of the thorax; but in many birds this would leave almost nothing for abdomen, and the limit would moreover fluctuate with almost every family of birds, the sternum being so variable in length. Practically, therefore, without reference to the breast-bone, "breast" or *pectus* is restricted to the *swelling* anterior part of gastræum, which we call belly or *abdomen* as soon as it begins to straighten out and flatten. Abdomen, like pectus, rounds up on either hand into sides; behind, it ends definitely in a transverse line passing across the anus. It has been unnecessarily divided into *epigastrium* or "pit of the stomach," and *venter* or lower belly; but these terms are rarely used. (*Crissum* is a word constantly used for some indefinite region immediately about the vent; sometimes meaning

the flank, sometimes the vent-feathers or under tail-coverts proper; I refer to it again in connection with these last.) Though these boundaries seem fluctuating and not perfectly satisfactory, a little practice will enable the student to appreciate their proper use in descriptions, and to employ them himself with sufficient accuracy. The adjectival terms are respectively *pectoral*, *abdominal*, and *lateral*. The anterior continuation of the trunk, or the

Neck (Lat. *collum*) is likewise subdivided into regions. Its lateral aspects, except in those birds that have lateral neck-tracts of feathers, are formed by the meeting over its sides of the feathers that grow on the dorsal and ventral pterylæ, the skin being usually not planted with feathers. Partly on this account, perhaps, a distinctively named region is not often expressed; we say simply "sides of the neck," or "neck laterally" (*parauchenia;* Fig. 25, 9). The neck behind, or the dorsal (upper) aspect, is divided into two portions: a lower, the "hind neck" proper, or "scruff of the neck" (Lat. *cervix;* Fig. 25, 8), next to the back; and an upper, or "nape of the neck" (Lat. *nucha;* Fig. 25, 7), adjoining the hind head. These are otherwise respectively known as the *cervical* and *nuchal region;* and, in speaking of both together, we usually say "the neck behind." The front of the neck has been needlessly subdivided, and these subregions vary with almost every writer. It suffices to call it *throat* (Lat. *gula*, Fig. 25, 37, or *jugulum*, 34); remembering that the *jugular* portion is lowermost, vanishing in breast, and the *gular* uppermost, running into chin along the under surface of the head. *Guttur* is a term sometimes used to include gula and jugulum together: it is simply equivalent to "throat," as just defined; the adjective is *guttural*. Though generally covered with feathers, the neck, unlike the trunk, is frequently partly naked. When naked behind, it is usually cervix that is bare, as so characteristically occurs in herons, from interruption of the forward extension of the pteryla spinalis. Nucha is seldom if ever naked, except as an extension of general bald-headedness. Gula is similarly naked from above downwards, as conspicuously illustrated in the order *Steganopodes*, comprising the pelicans, cormorants, etc., which have a bare gular pouch; and as seen in many vultures, whose baldness extends over nucha and gula, and even all around the neck, as in the condor, whose nakedness ends with so singular a collar of close-set, downy feathers. The lower throat or jugulum becomes naked in a few birds, in which a distended crop or craw protrudes, pushing apart feathers of two branches of the *pteryla ventralis* as these ascend the neck. The rule is, that the neck is not the seat of enlarged or otherwise highly developed feathers, which might restrict the requisite freedom of its motion; but there are some signal exceptions, among which may be instanced the

grouse family. The ruffed grouse[1] has a singular umbrella-like tuft on each side of the neck: the pinnated grouse[2] has still more curious winglets in the same situation, covering bare distensible skin: the sharp-tailed grouse[3] is in somewhat similar but less pronounced case; while the cock-of-the-plains[4] has some extraordinary jugular developments of feathers in connection with his subcutaneous tympanum. Cervix proper almost never has modified feathers, but often a transverse coloration different from that of the rest of the upper parts; when conspicuous, this is called "cervical collar," to distinguish it from the guttural or jugular "collars" or rings of colour. Nucha is frequently similarly marked with a "nuchal band"; often special developments there take the form of *lengthening* of the feathers, and we have a "nuchal crest." More particularly in birds of largely variegated colours, guttur and jugulum are marked *lengthwise* with stripes and streaks, of which those on the sides are apt to be different from those along the middle line in front. Jugulum occasionally has lengthened feathers, as in many herons. Higher up, the neck in front may have variously lengthened or otherwise modified feathers. Conspicuous among these are the *ruffs*, or tippets, of some birds, especially of the grebe family (*Podicipedidæ*), and, above all other English birds, of the male ruff (*Machetes pugnax*). But these, and a few other modifications of the feathers of the upper neck, are more conveniently considered with those of the

Head.—Though smaller than any of the areas already considered, the head has been more minutely mapped out, and much detail is required by the number and importance of its recognisable parts or regions. Without intending to mention all that have been named, I describe all needed to be known for any practical purposes.

"Top of the head" is a collective term for all the upper surface, from base of bill to nape, and laterally to about the level of the upper border of the eyes; this is the *pileum* or "cap" (Fig. 25, 1, 4, 6); it is divided into three portions. The *forehead*, or frontal region, or simply "the front" (Lat. *frons;* Fig. 25, 1), includes all that slopes upward from the bill,—generally to about opposite the anterior border of the eyes. *Middle head* or crown (Lat. *corona*) or *vertex* (Lat. Fig. 25, 1) includes the top of the head proper, or highest part, from the rise of the forehead to the fall of the hind-head towards nucha. This slope is the *hind-head*, or *occiput* (Lat. Fig. 25, 6). The lateral border of all three constitutes the superciliary line, that is, the line over the eye (Lat. *super*, over; *cilia*,

[1] *Bonasa umbellus,* which closely resembles the European hazel-grouse, *B. betulina.*
[2] *Cupidonia cupido.*
[3] *Pediœcetes phasianellus.*
[4] *Centrocercus urophasianus.*

little hairs, especially of the brows). "Crown" is often used as the same thing as pileum. The adjectives of the several words are *frontal*, *coronal* or *vertical*, and *occipital:* pileum has none in use, coronal being said instead.

"Side of the head" is a general term defining itself; it presents for consideration several regions. The *orbital* or *circum-orbital* region, or simply the *orbit* (Lat. *orbis*, an orb, here the socket of the eyeball; Fig. 25, 3), is a small space forming a ring around the eye. It includes the eye, and especially the eyelids (Lat. *palpebræ*). The points where these meet, in front and behind, respectively, are the *anterior canthus* and *posterior canthus* (Gr. κανθός, *kanthos*, Lat. *canthus*, a tire). The orbital region is subdivided into *supra-orbital*, *infra-orbital*, *ante-orbital*, and *post-orbital*, according as its upper, under, front, or back portion is desired to be specially designated. The situation of the orbit varies much in different groups of birds; it is generally midway, as said above, but may be higher or lower, pressed on toward the bill, or pushed far up and back, as strikingly shown in the woodcock (*Scolopax rusticula*). In owls, the orbital region is exaggerated into a great disk of radiating feathers, conferring a peculiar physiognomy. The *aural* or *auricular* (Lat. *auris*, or *auriculum*, ear; Fig. 25, 35) region lies about the external opening of the ear, or *meatus auditorius;* its position varies in heads of different shapes, but it nearly always lies behind and a little below the eye. Wherever located, it may be recognised at a glance, by the peculiar texture of the feathers (the *auriculars*) which overlie the meatus. Doubtless to offer least obstacle to sound, these are a parcel of loose-webbed little plumes, which may be collectively raised and turned forward, exposing the orifice of the ear; they are extremely large and notable in those owls which have complicated external ear-parts, and in such they form part of the great facial disc. The term "temporal region" or "temple" is not often used in ornithology, not being well distinguished from the post-orbital space between eye and ear, and having nothing special about it. At the lowermost back corner of the side of the head, generally just behind and below the ear, may be seen or felt a hard protuberance; it is the sharpest corner-stone of the head, being the place where the lower jaw hinges upon the skull. This is called the "angle of the jaw;" it is a good landmark, which must by no means be confused with the "angle of the mouth," where the horny parts of the beak come together. The *lore* (Lat. *lorum*, a strap, or bridle; hence, place where the cheek-strap passes; Fig. 25, 2) includes pretty much all the space between the eye and the side of the base of the upper mandible; a considerable part of it is simply ante-orbital. Thus we say of a hawk, "lores bristly;" and examination of a bird of that kind will show how large a space is

covered by the term. Lore, however, should properly be restricted to a narrow line between the eye and bill in the direction of the nostrils. It is excellently shown in the heron and grebe families, where "naked lores" is a distinctive character. The lore is an important place, not only from being thus marked in many birds, but from being frequently the seat of specially modified or specially coloured feathers. The rest of the side of the head, including the space between angle of jaw and bill, has the name of *cheek* (Lat. *gena*, first eyelid, then, and generally, the prominence under the eye formed by the cheek-bones; Fig. 25, 36). It is bounded above by loral, infra-orbital, and auricular regions; below, by a more or less straight line, representing the lower edge of the bony prong of the under mandible. It is cleft in front for a varying distance by the backward extension of the gape of the mouth; above this gape is more properly *gena*, or *malar region* (Lat. *mala*, upper jaw) in strictness; below it is *jaw* (*maxilla*), or rather "side of the jaw." The lower edge of the jaw definitely separates the side of the head from the "under surface" of the head; properly bounded behind by an imaginary line drawn straight across from one angle of the jaw to the other, and running forward to a point between the forks of the under mandible. As already hinted, "throat" (*gula*; Fig. 25, 37) extends upward and forward into this space without obvious dividing line; it runs into *chin* (Lat. *mentum*; Fig. 25, 38), of which it is only to be said that it is the (varying in extent) anterior part of the under surface of the head. Anteriorly, it may be conveniently marked off, opposite the point where the feathers end on the side of the lower jaw, from the feathery space (when any) *between* the branches of the upper mandible itself; this latter is called the *interramal* space (Lat. *inter*, between, *ramus*, fork).

The head is so often marked lengthwise with different colours, apt to take such definite position, that these lines have received special names. *Median vertical line* is one along the middle of pileum, from base of bill to nucha: *lateral vertical lines* bound it on either side. *Superciliary line* has already been noticed; below it runs the *lateral stripe*; that part of it before the eye is loral or ante-orbital; behind the eye, post-orbital; when these are continuous through the eye, they form a *transocular* (Lat. *trans*, across; *oculus*, eye) *line*; below this is *malar line*, or cheek-stripe (Lat. *frenum*, a bridle); below this on the under jaw, *maxillary* or *submaxillary line*; in the middle below, *mental* (L. *mentum*, chin) or *gular lines*.

No other part of the body has so variable a ptilosis as the head. In the great majority of birds it is wholly and densely feathered; it ranges from this to wholly naked; but nakedness, it should be observed, means only absence of perfect feathers, for most birds with unfeathered heads have a hair-like growth of filoplumes on the

skin. Examples of naked-headed birds are the turkey, the vultures, the cranes, and some of the heron tribe, as ibises. Associated with more or less complete baldness, is the frequent presence of various fleshy outgrowths, as *combs*, *wattles*, *caruncles*, *lobes*, and *flaps* of all sorts, even to enumerate which would exceed our limits. The parts of the barn-yard cock exemplify the whole. Sometimes *horny plates* take the place of feathers on part of the head; as the frontal shields of the coots and gallinules. A very common form of head-nakedness marks one whole order of birds, the *Steganopodes*, which have mentum and more or less of gula naked and transformed into a sort of pouch, extremely developed in the pelicans, and well seen in the cormorants. The next commonest is definite bareness of the lores, as in all herons and grebes; in the former including the whole circum-orbital region. A little orbital space is bare in many birds, as the vulturine hawks, and some pigeons; species of grouse have a bare warty supra-orbital space. Among water birds particularly, more or less of the interramal space is almost always unfeathered; the nakedness always proceeds from before backwards.

The opposite condition, that of redundant feathering, gives rise to all the various crests (Lat. pl. *cristæ*) that form such striking ornaments of many birds. Crests proper belong to the top of the head, but may be also held to include those growths on its side; these together being called crests in distinction to the ruffs, ruffles, beard, etc., of gulla or mentum. Crests may be divided into two kinds: 1, where the feathers are simply lengthened or otherwise enlarged; and 2, where the texture, and sometimes even the structure, is altered. Nearly all birds possess the power of moving and elevating the feathers on the head, simulating a slight crest in moments of excitement. The general form of a crest is a full, soft elongation of the coronal feathers collectively; when perfect, such a crest is *globular*, as in the Neotropical genus *Pyrocephalus;* generally, however, the feathers lengthen on the occiput more than on the vertex or front, and this gives us the simplest and commonest form. Such crests, when more particularly occipital, are usually connected with lengthening of nuchal feathers, and are likely to be of a thin, pointed shape, as is well shown in the lapwing (*Vanellus cristatus*). Coronal or vertical crests proper are apt to be rather different in coloration than in specially marked elongation of the feathers; they are perfectly illustrated in the goldcrest, and other species of the genus *Regulus*. Frontal crests are the most elegant of all; they generally rise as a pyramid from the forehead, as excellently shown in the crested titmouse (*Parus cristatus*) and others. All the foregoing crests are generally single, but sometimes double; as shown in the two lateral occipital tufts of the "horned" lark (*Eremophila*

alpestris), in all the "horned" owls, and in a few cormorants. Lateral crests are always double, one on each side of the head; they are of various shapes, but need not be particularised here, especially since they mostly belong to the second class of crests,—those consisting of texturally modified feathers. It is a general, though not exclusive, character of these last that they are *temporary;* while the other kind is only changed with the general moult, these are assumed for a short period only, the breeding season; and, furthermore, they are often distinctive of *sex*. Occurring on the top of the head, they furnish the most remarkable ornaments of birds. I need only instance the elegant helmet-like plumes of the partridges of the genus *Lophortyx;* the graceful flowing train of *Oreortyx;* the somewhat similar plumes of the night-herons. The majority of the cormorants, and many of the auks, possess lateral plumes of similar description; these, and those of the herons, are probably—in most cases certainly—*deciduous;* while those of the partridges above mentioned last as long as the general plumage. These lateral plumes, in many birds, especially among grebes, are associated with, and, in fact, coalesce with, the ruffs, which are singular lengthening and modifying in different ways of feathers of auriculars, genæ, and gula; and are almost always temporary. *Beards*, or special lengthening of the mental feathers alone, are comparatively rare; a European vulture, *Gypaëtus barbatus*, is a good example. The feathers sometimes become *scaly* (*squamous*), forming, for instance, the exquisite gorgelets or frontlets of humming-birds. They are often *bristly* (*setaceous*), as about the lores of nearly all hawks. A particular set of bristles, which grow in single series along the gape of many birds, are called *rictal bristles* or *vibrissæ*. These occur in greater or less development in most small insectivorous birds; they are large and stiff and highly characteristic of the family *Muscicapidæ* or flycatchers; while in some of the goatsuckers (*Caprimulgidæ*) they are prodigiously long, and in one species of that family (*Antrostomus carolinensis*) they have lateral filaments. While usually all the unlengthened head-feathers point backward, they are sometimes *erect* forming a velvety pile, or they may radiate in a circle from a given point, as from the eye in most owls, where they form a *facial disk*.

Of the Members: their Parts and Organs

I. THE BILL

The Bill (Lat. *rostrum*) is hand and mouth in one: the instrument of *prehension*. As hand, it takes, holds, and carries food or other substances, and in many instances feels; as mouth, it tears, cuts, or crushes, according to the nature of the substances taken;

assuming the functions of both lips and teeth, neither of which do any recent birds possess. An organ thus essential to the prime functions of birds, one directly related to their various modes of life, is of much consequence in a taxonomic point of view; yet its structural modifications are so various and so variously interrelated, that it is more important in framing genera than families or orders; more *constant* characters must be employed for the higher groups. The general shape of the bill is referable to the cone; it is the anterior part of the general cone that we have seen to reach from its point to the base of the skull. This shape confers the greatest strength combined with the greatest delicacy; the end is fine to apprehend the smallest objects, while the base is stout to manipulate the largest. But in no bird is the cone expressed with entire precision; and, in most, the departure from this figure is great. The bill always consists of two, the upper and the lower

Mandibles (Fig. 26), which lie, as their names indicate, above and below, and are separated by a horizontal fissure,—the mouth. Each mandible always consists of certain projecting skull-bones, sheathed with more or less *horny* integument in lieu of true skin. The framework of the Upper Mandible is (chiefly) a bone called the *intermaxillary*, or better, the *premaxillary*. In general, this is a three-pronged or tripodal bone running to a point in front, with the uppermost prong, or foot, implanted upon the forehead, and the other two, lower and horizontal, running into the sides of the skull. The scaffold of the Under Mandible is a compound bone called *inferior maxillary*; it is U- or V-shaped, with the point or convexity in front and the prongs running to either side of the base of the skull behind, to be there movably hinged. These two bones, with certain accessory bones of the upper mandible, as the *palate* bones, etc., together with the horny investment, constitute the *Jaws*. Both jaws, in birds, are movable; the under, by the joint just mentioned; the upper, either by a joint at, or by the elasticity of the bones of, the forehead; it is moved by a singular muscular and bony apparatus in the palate, further notice of which is given beyond, under head of Anatomy (Osteology). The motion of the upper mandible is freest and most extensive in the parrot tribe, where both fronto-maxillary and palato-maxillary sutures exist. When closed, the jaws meet and fit along their apposed edges or surfaces,

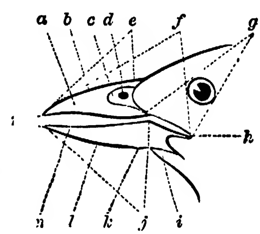


FIG. 26.—Parts of a Bill. *a*, side of upper mandible; *b*, culmen; *c*, nasal fossa; *d*, nostril; *e* (see below); *f*, gape, or whole commissural line; *g*, rictus; *h*, commissural point or angle of the mouth; *i*, ramus of under jaw; *j*, tomia of under mandible (the reference lines *e* should have been drawn to indicate the corresponding tomia of upper mandible); *k*, angle of gonys; *l*, gonys; *m*, side of under mandible; *n*, tips of mandibles.

in the same manner and for the same purposes as the lips and teeth of man or other vertebrate animals. All bills, thus similarly constituted, have been divided by the author into

Four Classes, representing as many ways in which the two mandibles close upon each other at the end. 1. The *epignathous* (Gr. ἐπί, *epi*, upon, γνάθος, *gnathos*, jaw) way, plan, or type, in which the upper mandible is longer than the under, and its tip is evidently bent down over the tip of the lower. 2. The *hypognathous* (Gr. ὑπό, *hupo*, under), in which the lower mandible is longer than the other. 3. The *paragnathous* (Gr. παρά, *para*, at or by), in which both are of about equal length, and neither is evidently bent over the other. 4. The *metagnathous* (Gr. μετά, *meta*, with, beside, etc.), in which the points of the mandibles cross each other. The second and fourth of these are extremely rare; they are exemplified, respectively, by the skimmer and the crossbill (genera *Rhynchops* and *Loxia*). The first is common, occurring throughout the birds of prey, the parrots, and among the petrels, gulls, etc. etc. The great majority of birds exhibit the third; and, among them, there is such evident gradation into epignathism, that it is necessary to restrict the latter to its complete development, exhibited in the intermaxillary bone divested of its horny sheath, which often, as among flycatchers, etc., forms a little overhanging point, but does not constitute epignathism. These classes, it should be added, though always applicable, and very convenient in descriptions, are purely arbitrary, that is, they by no means correspond to any four large groups of birds; but, on the contrary, usually only mark families and the subdivisions of families; and the four types may be seen in closely related genera. The general shape of the bill has also furnished

Other Classes, for many years used as a large basis for ornithological classification, even for the establishment of orders; but which the progress of the science has shown to be merely as convenient as, and only less arbitrary than, the foregoing. The principal of these are represented by the following types: A, among land birds. 1. The *fissirostral* (Lat. *fissus*, cleft, and *rostrum*), or cleft, in which the bill is small, short, and with a very large gape running down the side of the head; as in the swallow, chimney-swift, goatsucker. 2. The *tenuirostral* (Lat. *tenuis*, slender), or slender, in which the bill is narrow, long, and with a short cleft; as in the humming-bird, creeper, nuthatch. 3. The *dentirostral* (Lat. *dens*, a tooth), or toothed, in which, with a various general shape, there is present a nick, tooth, or evident lobe in the apposed edges of one or both mandibles near the end; as in the shrike and some wrens, thrushes, and warblers. 4. The *conirostral* (Lat. *conus*, a cone), or conical, sufficiently defined by its name, and illustrated by the great

finch or bunting family and some allied ones.—B, among water birds. 5. The *longirostral* (Lat. *longus*, long), or long, an aquatic style of the tenuirostral, best exhibited in the great snipe family. 6. The *pressirostral* (Lat. *pressus*, pressed), or the compact, illustrated by the plovers, etc. 7. The *cultrirostral* (Lat. *culter*, a knife), cutting, exemplified in the heron group. 8. The *lamellirostral* (Lat. *lamella*, a plate), in which the bill is broad and plated with a series of tooth-like processes, as in the duck tribe. None of these terms are now used to indicate natural groups, nor have we such absurdities as the "orders" *Fissirostres*, *Tenuirostres*, etc. A swallow, for instance, and a swift are equally fissirostral, though only distantly related to each other; a swift is closely related to a humming-bird, though the latter is extremely tenuirostral; and birds of contiguous genera may be dentirostral or not. The words are nevertheless convenient incidental terms in general descriptions. Various other similar terms, expressing special modifications, as *latirostral* (Lat. *latus*, broad), *acutirostral* (Lat. *acutus*, sharp), etc., are also employed as common adjectives.

Other Forms.—A bill is called *long*, when notably longer than the head proper; *short*, when notably shorter; *medium*, in neither of these conditions. It is *compressed*, when higher than wide, at the base at least, and generally for some portion of its length; *depressed*, when wider than high; *terete* (Lat. *teres*, cylindric), under neither of these conditions. It is *recurved*, when curved upward; *decurved*, when curved downward; *bent*, when the variation in either direction is at an angle; *straight*, when not out of line with the axis of the head. A bill is *obtuse* (said chiefly of the paragnathous sort) when it rapidly comes to an end that therefore is not fine; or when the end is knobby; it is *acute* when it runs to a sharp point; *acuminate*, when equally sharp and slenderer; *attenuate*, when still slenderer; *subulate* (awl-shaped), when slenderer still; *acicular* (needle-shaped), when slenderest possible, as in some humming-birds. A bill is *arched*, *vaulted*, *turgid*, *tumid*, *inflated*, etc., when its outlines, both crosswise and lengthwise, are notably more or less convex; and *contracted*, when some, or the principal, outlines are concave (said chiefly of depressions about the base of the upper mandible, or of concavity along the sides of both mandibles). A bill is *hamulate* (Lat. *hamus*, a hook), or *unguiculate* (Lat. *unguis*, a claw), when strongly epignathous, as in rapacious birds, where the upper mandible is like the talon of a carnivorous beast; it is *dentate*, when toothed, as in a falcon; if there are a number of similar "teeth," it is *serrate* (Lat. *serra*, a saw), like a saw; it is *cultrate* (knife-like), when extremely compressed and sharp-edged, as in the auk, skimmer: if much curved as well as cultrate, it is *falcate* (Lat. *falx*, a reaping-hook; scythe-shaped); and each mandible may be

oppositely falcate, as in the crossbill, constituting metagnathism. A bill much flattened and widened at the end (rare) is *spatulate* (Lat. *spatula*, a spoon); examples: spoonbill, shoveller duck. One is called *lamellate*, when it has a series of plates or processes just inside the edges of the mandibles; as in all the duck order, and in a few petrels; the design is to furnish a sifter or strainer of water, just what is effected in the whale, by the baleen in its mouth. Finally, the far end of the bill, of whatever shape, is called the *tip* or *apex* (Fig. 26, *n*); the near end, joined to the rest of the skull, the *base*; the rest is the *continuity*. Some other features of the bill as a whole are best treated under the separate head of

The Covering of the Bill.—(*a.*) In the great majority of birds, including nearly all perchers, many walkers, and some waders and swimmers, the sheathing of the mandibles is wholly *hard*, *horny*, or *corneous* (Lat. *cornu*, a horn); it is integument modified much as in the case of the nails or claws of beasts. In nearly all waders, and most swimmers, the sheath becomes, wholly or partly, softer, and is of a dense, leathery texture. But some swimmers, as among the auks, furnish bills as hard-covered as any, while some perchers have it partly quite soft, so that no unexceptional rule can be laid down; and, moreover, the gradations from one extreme to the other are insensible. Probably the softest bill is found among the snipes, where it is skinny throughout, and in typical snipes and woodcocks vascular and nervous at the tip, becoming a true organ of touch, used to feel for worms out of sight in the mud. In all the duck order the bill is likewise soft; but there it is always terminated by a hard, horny *unguis* or "nail," more or less distinct; and such a horny claw also occurs in other water birds with softish bills, as the pelican. An interesting modification occurs in all, or nearly all, of the pigeon order; these birds have the bill hard or hardish at tip and through most of continuity, but towards and at the base of the upper mandible the sheath changes to a soft, tumid, skinny texture, overarching the nostrils; it is much the same with most plovers. But the most important feature in this connection is afforded by the parrots and all the birds of prey: one so remarkable that it has received a distinct name: CERE. The cere (Lat. *cera*, wax; because it looks waxy) is a dense membrane saddled on the upper mandible at base, so different from the rest of the bill, that it might be questioned whether it does not more properly belong to the head than to the bill, were it not for the fact that the nostrils open in it. Moreover, the cere is often densely feathered, as in the Carolina paroquet, in the bill proper of which no nostrils are seen, these being hidden in the feathered cere, which, therefore, might easily be mistaken at first sight for the bird's forehead. A sort of false cere occurs in some water birds, as the jaegers, or skua-gulls (genus

Stercorarius). The tumid nasal skin of pigeons is sometimes called a cere; but the term had better be restricted to the birds first above named. The under mandible probably never presents softening, except as a part of general skinniness of the bill; it may have a nail at the end. (*b.*) The covering is either *entire* or *pieced.* In most birds it is entire; that is, the sheath of either mandible may be pulled off whole, like the finger of a glove. It is, however, in many birds divided into parts, by various lines of slight connection, and then comes off in pieces; as is the case with some water birds, particularly petrels, where the divisions are regular, and the pieces have received distinctive names. Many auks (*Alcidæ*) have the covering of the bill in particular pieces, and it is an extraordinary fact that such parts are of a secondary sexual character, being assumed at the breeding season and afterwards *moulted* like feathers. Such condition of the sheath of the beak, or of special developments of the sheath, is called *caducous* or *deciduous.* The entire covering of both jaws together is called *rhamphotheca* (Gr. ῥάμφος, *hramphos*, beak; θήκη, *theke*, a sheath); of the upper alone, *rhinotheca* (Gr. ῥίς, *hris*, the nose); of the under, *gnathotheca* (Gr. γνάθος, *gnathos*, jaw); but these terms are not much used. (*c.*) The covering is otherwise variously marked; sometimes so strongly that similar features are impressed upon the bones themselves beneath. The most frequent marks are various *ridges* (Lat. pl. *carinæ*, keels) of all lengths and degrees of expression, straight or curved, vertical, oblique, horizontal, lengthwise, or transverse; a bill so marked is said to be *striate* (Lat. *stria*, a streak) or *carinate;* when numerous and irregular, they are called *rugæ* (Lat. *ruga*, a wrinkle) and the bill is said to be *corrugated* or *rugose.* When the elevations are in points or spots instead of lines, they are called *puncta* (Lat. *punctum*, a point); a bill so furnished is *punctate*, but the last word is oftener employed to designate the presence of little *pits* or depressions, as in the dried bill of a snipe towards the end. Larger softish, irregular knobs or elevations pass under the general name of *warts* or *papillæ*, and a bill so marked is *papillose;* when the processes are very large and soft, the bill is said to be *carunculate* (Lat. *caro*, flesh, diminutive *carunculus*, little bit of flesh). Various linear *depressions*, often but not always associated with carinæ, are grooves or *sulci* (Lat. *sulcus*, a furrow), and the bill is then called *sulcate.* Sulci, like carinæ, are of all shapes, sizes, and positions; when very large and definite, they are sometimes called *canaliculi*, or channels. The various knobs, "horns," and large special features of the bill cannot be here particularised. Any of the foregoing features may occur on both mandibles, and they are exclusive of that special mark of the upper (the nasal *fossa*) in which the nostrils open, and which is considered below. We have still to

notice the special parts of either mandible; and will begin with the simplest, the

Under Mandible.—In the majority of birds it is a little shorter and a little narrower and not nearly so deep as the upper; but sometimes quite as large, or even larger. The upper edge, double (*i.e.* there is an edge on both sides), is called the mandibular *tomium*, or in the plural, *tomia* (Gr. τέμνειν, *temnein*, to cut; Fig. 26, *j*), as far as it is hard; this is received against, and usually a little within, the corresponding edge of the upper mandible. The prongs already mentioned are the mandibular *rami* (pl. of Lat. *ramus*, a branch; Fig. 26, *i*); these meet at some point in front, either at a short angle (like >) or with a rounded joining (like ⊃). At their point of union there is a prominence, more or less marked (Fig. 26, *k*); this is the *gonys.* That is to say, this point is gonys proper: but the term is extended to apply to the whole line of union of the rami, from gonys proper to the tip of the under mandible; and in descriptions it means, then, the *under outline of the bill* for a corresponding distance (Fig. 26, *l*). This important term must be understood; it is constantly used in describing birds. The gonys is to the under mandible what the keel is to a boat; it is the opposite of the ridge or *culmen* of the upper mandible. It varies greatly in length. Ordinarily it forms, say, one-half to three-fourths of the under outline. Sometimes, as in conirostral birds, a sparrow, for example, it represents nearly all this outline; while in a few birds it makes the whole, and in some, as the puffin, is actually longer than the lower mandible proper, because it extends backwards in a point. Other birds may have almost no gonys at all; as a pelican, where the rami only meet at the extreme tip, or in the whole duck family, where there is hardly more. As the student must see, the length of the gonys is simply a matter of how extensive is the fusion of the rami; and that, similarly, their mode of fusion, as in a sharp ridge, a flat surface, a straight line, a curve, etc., results in corresponding modifications of its special shape. The *interramal space* is complementary to length of gonys: sometimes it runs to the tip of the bill, as in a pelican, sometimes there is next to none, as in a puffin; while its width depends upon the degree of divergence, and the straightness or curvature, of the rami. The surface between the tomium and lower edge of rami and gonys together is the *side of the under mandible* (Fig. 26, *m*). The most important feature of the

Upper Mandible is the *culmen* (Lat. for top of anything; Fig. 26, *b*). The culmen is to the upper mandible what the ridge is to the roof of a house; it is the upper profile of the bill—the *highest middle lengthwise line of the bill;* it begins where the feathers end on the forehead, and extends to the tip of the upper mandible.

According to the shape of the bill it may be straight or convex, or concave, or even somewhat ∽-shaped; or double-convex, as in the tufted puffin: but in the great majority of cases it is convex, with increasing convexity towards the tip. Sometimes it rises up into a thin elevated crest, as well shown in the genus *Crotophaga*, and in the puffins (*Fratercula*), when the upper mandible is said to be *keeled*, and the culmen itself to be *cultrate;* sometimes it is really a furrow instead of a ridge, as toward the end of a snipe's bill; but generally it is simply the uppermost line of union of the gently convex and sloping sides of the upper mandible (Fig. 26, *a*). In a great many birds, especially those with depressed bill, as all the ducks, there is really no culmen; but then the median lengthwise line of the surface of the upper mandible takes the place and name of culmen. The culmen generally stops short about opposite the proper base of the bill; then the feathers sweep across its end, and downwards across the base of the sides of the upper mandible, usually also obliquely backwards. Variations in both directions from this standard are frequent; the feathers may run out in a point on the culmen, shortening the latter, or the culmen may run a way up the forehead, parting the feathers; either in a point, as in the rails and gallinaceous birds, or as a broad plate of horn, as in the coots and gallinules. The lower edge (double) of the upper mandible is the *maxillary tomium*, as far backward as it is hard and horny. The most conspicuous feature of the upper mandible in most birds is the

Nasal Fossa (Lat. *fossa*, a ditch), or *nasal groove* (Fig. 26, *c*), in which the nostrils open. The upper prong of the intermaxillary bone is usually separated some ways from the two lateral prongs; the skinny or horny sheath that stretches betwixt them is usually sunken below the general level of the bill, especially in those birds where the prongs are long or widely separated; this "ditch" is what we are about. It is called *fossa* when short and wide, with varying depth; *sulcus* or groove when long and narrow; the former is well illustrated in the gallinaceous birds; the latter in nearly all wading birds and many swimmers. When the intermaxillary prongs are soldered throughout, or are very short and close together, there is no (or no evident) nasal depression, the nostrils then opening flush with the level of the bill. The

Nostrils (Fig. 26, *d*), two in number, vary in *position* as follows:—they are *lateral*, when on the sides of the upper mandible (almost always); *culminal*, when together on the ridge (rare); *superior* or *inferior* when evidently above or below midway betwixt culmen and tomia; they are *basal*, when at the base of the upper mandible; *sub-basal* when near it (usual); *median* when at or near the middle of the upper mandible (frequent, as in cranes, geese,

etc.); *terminal* when beyond this (very rare; probably there are *now no birds with nostrils* at the end of the bill, except the *Apteryx*). The nostrils are *pervious*, when open, as in nearly all birds; *impervious*, when not visibly open, as among cormorants and other birds of the same order; they are *perforate* when there is no *septum* (partition) between them, so that you can look through them from one side of the bill to the other, as in the turkey-buzzard, crane, etc.; *imperforate* when partitioned off from each other, as in most birds; but different ornithologists use these terms interchangeably. The principal *shapes* of the nostrils may be thus exhibited:— a line, *linear* nostrils; a line variously enlarged at either end, *clavate*, *club-shaped*, *oblong*, *ovate* nostrils; a line, enlarged in the middle, *oval* or *elliptic* nostrils; this passing insensibly into the circle, *round* or *circular* nostrils; and the various kinds of more or less linear nostrils may be either longitudinal, as in most birds, or oblique, as in a few; very seldom directly transverse (up and down). Rounded nostrils may have a raised border or *rim*; when this is prolonged they are called *tubular*, as in some of the goatsucker family, and in all the petrels. Usually, the nostrils are defined entirely by the substance surrounding them; thus, of cere, in a hawk; of softish skin, in a pigeon, plover, or snipe; or of horn, in most birds; but often their contour is partly formed by a special development, somewhat distinct either in form or texture, and this is called the *nasal scale*. Generally, it forms a sort of overhanging arch or portico, as well shown in all the gallinaceous birds, among the wrens, etc. A very curious case of this is seen in the wryneck (*Iynx torquilla*), where the scale forms the floor instead of the roof of the nostrils. The nostrils also vary in being *feathered* or *naked*; the nasal fossa being a place where the frontal feathers are apt to run out in points (called *antiæ*), embracing the root of the culmen. This extension may completely fill and hide the fossa, as in many grouse and ptarmigan; but it oftener runs for a varying distance toward, or *above* and beyond, the nostrils; sometimes similarly below them, as in a chimney-swift; and the nostrils may be densely feathered when there is no evident fossa, as in an auk. When thus truly feathered in varying degree, they are still open to view; another condition is, their being covered over and hidden by modified feathers not growing on the bill itself, but on the forehead. These are usually bristle-like (*setaceous*), and form two tufts, close-pressed and directed forwards, as is perfectly shown in a crow; or, the feathers may be less modified in texture, and form either two *tufts*, one over each nostril, or a single *ruff*, embracing the whole base of the upper mandible; as in nuthatches, titmice, red-poll linnets, snow-buntings, and many other northern *Fringillidæ*. Bristles or feathers thus growing forward are called *retrorse* (Lat.

retrorsum, backward; here used in the sense of *in an opposite direction from* the lay of the general plumage; but they should properly be called *antrorse*, *i.e.* forward). The nostrils, whether culminal or lateral, are, like the eyes and ears, always two in number, though they may be united in one tube, as in the petrels.

The Gape.—It only remains to consider what results from the relations of the two mandibles to each other. When the bill is opened, there is a cleft or fissure between them; this is the *gape* or *rictus* (Lat. *rictus*, mouth in the act of grinning). But while thus really meaning the open *space* between the mandibles, it is generally used to signify the *line of their closure*. *Commissure* (Lat. *committere*, to put or join together) means the point where the gape ends behind, that is, the *angle of the mouth*, *angulus oris*, where the apposed edges of the mandibles join each other; but, as in the last case, it is loosely applied to the whole line of closure, from true commissure to tip of the bill. So we say, "commissure straight," or "commissure curved"; also, "commissural edge" of either mandible (equivalent to "tomial edge") in distinction from culmen or gonys. But it would be well to have more precision in this matter. Let, then, *tomia* (Fig. 26, *j*) be the true cutting edges of either mandible from tip to opposite base of bill proper; *rictus* (Fig. 26, *g*) be their edges thence to the POINT *commissure* (Fig. 26, *h*) where they join when the bill is open; the LINE commissure (Fig. 26, *f*) to include both when the bill is closed. The gape is *straight*, when rictus and tomia are both straight and lie in the same line; *curved*, *sinuate*, when they lie in the same curved or waved line; *angulated*, when they are straight, or nearly so, but do not lie in the same line, and therefore meet at an angle. Angulation of the commissure is a distinctive character of most finches and buntings—*Fringillidæ*. It is well shown in the hawfinch, *Coccothraustes vulgaris*.

II. THE WINGS.

Definition.—Pair of anterior or *pectoral* limbs organised for flight by means of dermal outgrowths. Used for this purpose by birds in general; but by ostriches and their allies only as outriggers to aid running; by penguins as fins for swimming under water; used also in the latter capacity by some birds that fly well, as loons, cormorants, dippers. Wanting in no recent birds, but imperfect in a few, as all *Ratitæ*; greatly reduced in the emeu, cassowary, and kiwi-kiwi; also in the moas (*Dinornis*); in the Cretaceous *Hesperornis* only the rudimentary humerus is known. To understand their structure we must notice particularly

The Bony Framework (Figs. 27, 28, 29).—The skeleton of a bird's wing is built upon a plan common to the fore or pectoral

limb of all the higher vertebrates, so that its bones and joints may readily be compared and identified with those of any lizard or mammal, including man. But this member is highly specialised;

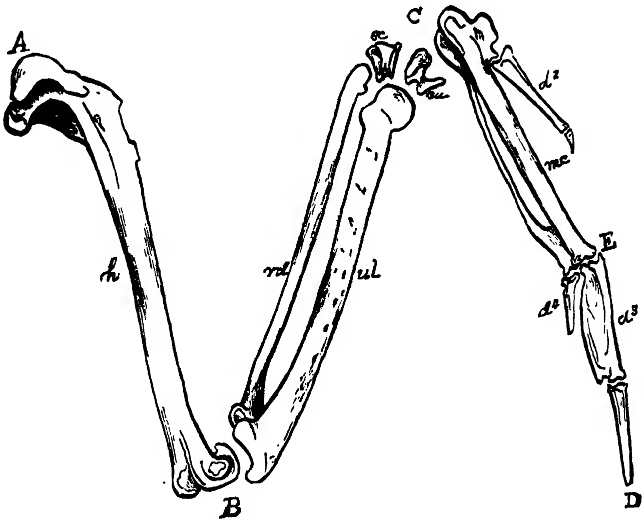


FIG. 27.—Bones of right wing of a duck, *Clangula islandica*, from above, ¾ nat. size. (Dr. R. W. Shufeldt, U.S.A.) *A*, shoulder, *omos*; *B*, elbow, *ancon*; *C*, wrist, *carpus*; *D*, end of principal finger; *E*, end of hand proper, *metacarpus*. *A B*, upper arm, *brachium*; *B C*, fore-arm, *antebrachium*; *C D*, whole hand or pinion, *manus*; composed of *C E*, hand proper or *metacarpus*, excepting d^2; *E D*, or d^2, d^3, d^4, fingers, digits, *digiti*. *h*, *humerus*; *rd*, *radius*; *ul*, *ulna*; *sc*, outer carpal, *scapholunare* or *radiale*; *cu*, inner carpal, *cuneiforme* or *ulnare*; these two composing wrist or *carpus*. *mc*, the compound hand-bone, or *metacarpus*, composed of three metacarpal bones, bearing as many digits—the outer digit seated upon a protuberance at the head of the metacarpal, the other two situated at the end of the bone. d^2, the outer or radial digit, commonly called the thumb or *pollex*, composed of two *phalanges*; d^3, the middle digit, of two phalanges; d^4, the inner or ulnar digit, of one phalanx; d^2 is the seat of the feathers of the *bastard wing* or *alula*. *D* to *C* (whole pinion), seat of the flight-feathers called *primaries*; *C* to *B* (forearm), seat of the *secondaries*; at *B* and above it in direction of *A*, seat of *tertiaries* proper; below *A*, in direction of *B*, seat of *scapularies* (upon pteryla humeralis), often called tertiaries. The wing shown half-spread: complete extension would bring *A B C D* into a right line; in complete folding *C* goes to *A*, and *D* to *B*; all these motions *nearly* in the plane of the paper. The elbow-joint and wrist are such perfect hinges, that, in opening or closing the wing, *C* cannot sink below the paper, nor *D* fly up above the paper, as would otherwise be the effect of the pressure of the air upon the flight-feathers. Observe also: *rd* and *ul* are two rods connecting *B* and *C*; the construction of their jointing at *B* and *C*, and with each other, is such that they can *slide lengthwise* a little upon each other. Now when the point *C*, revolving about *B*, approaches *A* in the arc of a circle, *rd* pushes on *sc*, while *ul* pulls back *cu*; the motion is transmitted to *D*, and makes this point approach *B*. Conversely, in opening the wing, *rd* pulls back *sc*, and *ul* pushes on *cu*, making *D* recede from *B*. In other words, the angle *A B C* cannot be increased or diminished without similarly increasing or diminishing the angle *B C D*; so that no part of the wing can be opened or shut without automatically opening or shutting the rest,—an interesting mechanism by which muscular power is correlated and economised. This latter mechanism is further illustrated in Fig. 28, where *rc* and *uc* show respectively the size, shape, and position of the radial condyle and ulnar condyle of the humerus. It is evident that in the flexed state of the elbow, as shown in the middle figure, the radius, *rd*, is so pushed upon that its end projects beyond *ul*, the ulna; while in the opposite condition of extension, shown in the lower figure, *rd* is pulled back to a corresponding extent.

being fitted for accomplishing flight, not only by the development of feathers, but also by modifications in the bones themselves. The axes of the bones have a special direction with reference to each

other and to the axes of the body; the movements of the joints are peculiar in some respects; and the whole extremity of the wing, from the wrist outward, is peculiarly constructed, by loss of some of the digits that five-fingered animals possess, and by the compression of those that are left. The wing proper begins at the shoulder-joint, where it hinges freely upon the shoulder, in a shallow or *glenoid* socket formed conjointly by the shoulder-blade or *scapula*, and by the *coracoid* bone; these two, with the clavicles, collar-bones, or merrythought, *furculum*, forming the *shoulder-girdle*, or *pectoral arch* (Figs. 56, 59).

The wing ordinarily consists, in adult life, of *ten* or *eleven* actually separate bones; in the embryo (see Fig. 29) there are indications of several more at the wrist-joint, which speedily lose

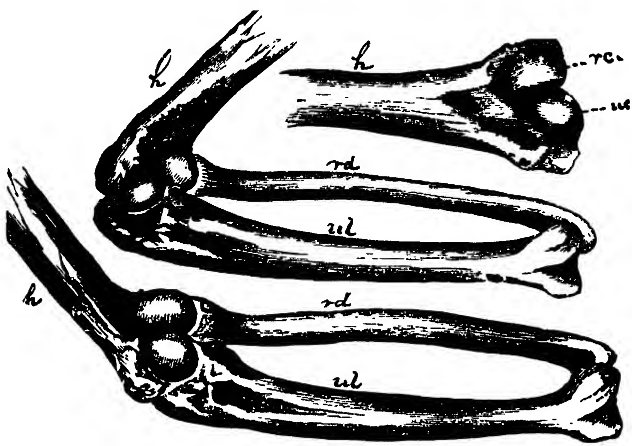


FIG. 28.—Mechanism of elbow-joint. (See explanation of Fig. 27.)

their individual identity by fusing together and with bones of the hand. Asidė from these, there is often an accessory ossicle at the shoulder-joint (Fig. 56, *ohs*), sometimes one at the wrist-joint, occasionally an extra bone at the end of the principal finger. The normal or usual number is shown in Fig. 27, taken from a duck (*Clangula islandica*), in which there are eleven.

The upper-arm bone *h*, reaching from the shoulder *A* to the elbow *B*, is the *humerus*. In the closed wing, the humerus lies nearly in the position of the same bone in man when the elbow is against the side of the body; in extension of the wing the elbow is borne away from the body, as when we raise the arm, but carry it neither forward nor backward. A peculiarity of the bird's humerus is, that it is rotated on its axis through about the quadrant of a circle, so that what is the front of the human bone is the outer

aspect in the bird. The humerus is a cylindric bone, straightish or somewhat italic-*f*-shaped, with a globular head to fit the socket of the shoulder, a strong pectoral ridge for insertion of the breast muscles, and at the bottom two *condyles* (Fig. 28, *rc*, *uc*) or joint-surfaces for articulation with a pair of succeeding bones. The forearm, *cubit* or *antebrachium*, extending from elbow to wrist, *B* to *C*, in Fig. 27, has two parallel bones of about equal lengths. These are the *ulna*, *ul*, and the *radius*, *rd*; the former, inner and posterior, the larger of the two, bearing the quills of the secondary series; the latter, slenderer, outer, and anterior. The enlarged proximal extremity of the ulna is called the *olecranon*, or, "head of the elbow." The third segment of the wing is the wrist or *carpus*. In adult life, this normally consists of two little knobby carpal bones, extremely irregular in shape, called the *scapholunare*, *sc*, and *cuneiforme*, *cu*. One being at the end of the radius, the other at that of the ulna, they are also called *radiale* and *ulnare*. In the embryo there is at least one other carpal bone, that early fuses with the next segment, and in many birds there are several such. This fourth segment is the *hand* proper, or *metacarpus*, *mc*, *C* to *E* (exclusive of *d* 2). The single metacarpal or hand-bone is very composite; that is, compounded of several; for, besides including certain carpal elements, as already said, it consists of three bones fused (in all recent birds) in one, corresponding to the three digits or fingers that birds possess. In fact it is three metacarpals in one. The metacarpal corresponding to the principal finger is much the largest of the three; that of the first finger is very short, being only the expanded part seen in the figure, just above the bone marked

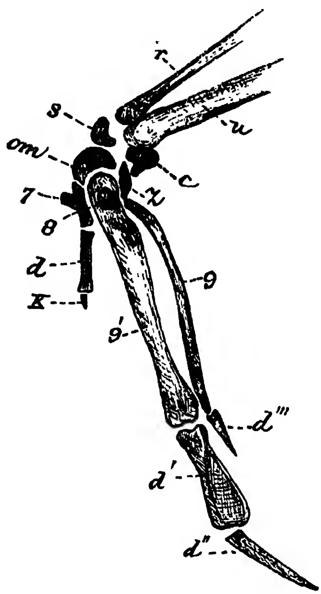


FIG. 29, from a *young* cock-of-the-plains (*Centrocercus urophasianus*, six months old) is designed to show the composition of the carpus and metacarpus before the elements of these bones fuse together: *r*, radius; *u*, ulna; *s*, scapholunar or radiale; *c*, cuneiform or ulnare; *om*, a carpal bone believed to be os magnum, later fusing with the metacarpus; *z*, a carpal bone, supposed to be unciform, later fusing with metacarpus; 8, an unidentified fifth carpal bone, which may be called *pentosteon*, later fusing with the metacarpus; 7, radial or outer metacarpal bone, bearing the pollex or outer digit, consisting of two phalanges, *d* and *k*; 9', principal (median) metacarpal bone, bearing the middle finger, consisting of the two phalanges, *d'*, *d''*; 9, inner or ulnar metacarpal, bearing a digit of one phalanx, *d'''*. The pieces marked *om*, *z*, 7, 8, 9, all fuse with 9' to form the single compound metacarpal bone marked *mc* in Fig. 27. (From nature, by Dr. R. W. Shufeldt, U.S.A.)

d 2; that of the third finger is nearly as long as the main metacarpal, but much slenderer, and usually fused only at its two ends, leaving between itself and the main metacarpal a considerable space, as seen opposite the letters *mc* in the figure. The wing is finished off with three fingers or *digits* marked *d* 2, *d* 3, *d* 4. The middle one of these, *E* to *D* in the figure, is much the largest, and forms the main continuation of the hand. The digit, *d* 3, ordinarily consists of two bones, called *phalanges*, placed end to end, as in the example before us; but occasionally there is found a third phalanx. The outer or radial digit, *d* 2, ordinarily consists of two bones, of

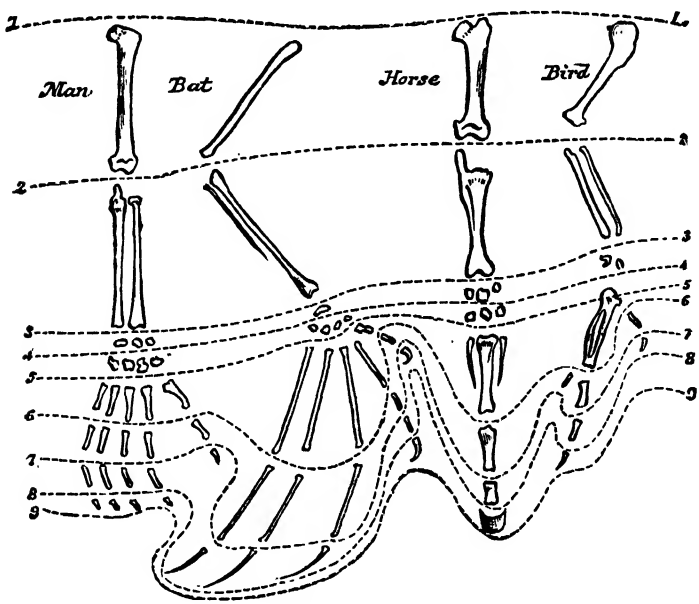


FIG. 29 *bis*.—Diagram of fore limbs of man, bat, horse, and bird. The lines 1-9 are *isotomes*, cutting the limbs into morphologically equal parts, or *isomeres*.

which the terminal one is small, and may be wanting. The inner or ulnar digit, *d* 4, consists of a single small phalanx, closely bound to the side of the middle finger. Corresponding to the compactness and consolidation of these terminal segments, the digits enjoy little individual motion. The outer or radial digit is the most independent one. In the *Archæopteryx* the three metacarpals were free bones, and the whole hand more like that of a lizard. No bird now has free metacarpals in adult life; none has more than three digits. These three are supposed by some to correspond to the thumb and fore and middle fingers of our hands; by others, to the

fore, middle, and ring fingers, and being consequently the second, third, and fourth digits, as marked in the figure. The digit marked *d* 2 is commonly called a bird's *thumb* or *pollex*. The *Apteryx* and the cassowaries have but one complete digit. The resemblance to a lizard's or quadruped's digits is increased by the *claws* which many birds possess, These may be borne on the enlarged terminal phalanx of *d* 2 (*k*, in Fig. 29), as is very well shown in the turkey-buzzard and other American *Cathartidæ;* both on this and on the terminal phalanx of *d* 3 (*d″* in Fig. 29), as in the ostrich; on the latter alone, as in the *Apteryx*, cassowary, American ostrich, and swan. The inner finger, *d* 4 (*d‴* in Fig. 29) is not known to ever bear a claw, excepting in *Archæopteryx*. The whole segment, *C* to *D*, is commonly called "the hand," "pinion," or *manus*, though, as we have seen, it consists of hand proper (metacarpus), and fingers (digits) with their respective phalanges. (Fig. 29 *bis*.)

Some other bones are observed in birds' wings. As already said, there is a supplementary ossicle in the shoulder-joint of many birds; it is badly called the *scapula accessoria* (Fig. 56, *ohs*). At the convexity of the elbow there may be one or more ossicles, not pertaining properly to the wing-skeleton, but developed in the tendons of muscles passing over the joint; they are *sesamoids*, like the human patella, or knee-cap. In various birds there is found at the convexity of the wrist, on the head of the metacarpal, an ossicle called the *os prominens;* apparently a sesamoid. Some other ossicles observed in the wrists of young or embryonic birds are all supposed to be carpal elements, the exact homologies of which may be still questioned.

The Mechanism of these Bones is admirable. The shoulder-joint is free, much like our own, permitting the humerus to swing all about; though the principal motions are to and from the side of the body (*adduction* and *abduction*), and up and down in a vertical plane. The elbow-joint is a very strict hinge, permitting motion in one plane, nearly that of the wing itself. The finger-bones have little individual motion. The construction of the wrist-joint is quite peculiar. In the first place the two bones of the forearm are so fixed in relation to each other, that the radius cannot roll over the ulna, like ours. If you stretch your arm upon the table, you can, without moving the elbow, turn the hand over so that either the palm or the knuckles are downward. This is a rotary motion of the bones of the forearm, called *pronation* and *supination;* the hand is prone when the palm touches the table, supine when the knuckles are downward. This rotation is absent from the bird's arm; if it could occur, the action of the air upon the pinion-feathers would throw them all "at sea" during the strokes of the wing, rendering flight difficult or impossible. The hinging of the

hand upon the wrist is such, also, that the hand does not move up and down, as ours can, in a plane perpendicular to the surface of the wing, but in the same plane as that surface. The motion is that which would take place in our hand if we could bring the little finger and its border of the hand so far around as to touch the corresponding border of the forearm. It is a motion of adduction, not of flexion, and its opposite, abduction, not extension, by which a wing is folded and spread. Such *abduction* is the way in which the hand is extended upon the wrist-joint, increasing and completing the unfolding of the wing that begins by the true extension of the forearm upon the elbow and abduction of the upper arm from the body. In a word, a wing is spread by the motion of abduction at the shoulder and wrist, of extension at the elbow; it is closed by adduction at the shoulder and wrist, and flexion at the elbow. The numerous muscles which unfold or straighten out the wing are called *extensors;* those that bend or close it are *flexors.* Extensors lie upon the back of the upper arm, and the front of the forearm and hand, their "leaders" or tendons passing over the *convexities* of the elbow and of the wrist. The flexors occupy the opposite sides of the limb, with tendons in the concavities of the joints. The most powerful muscles of the wings are the great *pectoral* or breast muscles, acting upon the upper end of the humerus; there are several of them, exerted in throwing out the arm from the body, and in giving both the up and down wing-strokes. Tendons are generally strong inelastic cords; but there is an interesting arrangement of an elastic cord in a bird's wing. In Fig. 27, *A B C* is a deep angle formed by the naked bones, but none such is visible from the exterior, because the space is filled by a fold of skin passing from *C* to near *A*. But *C* approaches and recedes from *A* as the wing is folded or unfolded, and a cord long enough to reach *A*-*C* would be slack in the folded wing, did not its elasticity enable it to contract and stretch, keeping the anterior border of the wing straight and smooth. (For another automatic mechanism, see Fig. 28.)

The point *C* is a highly important landmark in practical ornithology; it represents, in any folded wing, a very prominent point, the distance from which to the tip of the longest flight-feather is a special measurement known as that of "the wing." It is the convexity of the carpus, commonly called the "carpal angle," or "bend of the wing." Having thus glanced at the bony structure and mechanism of the wing, we are ready to examine the

Feathers of the Wing (Fig. 30).—How important these are will be evident from the consideration that they are the bird's chief organs of locomotion; for without them the wing would be useless for flight. We also remember that such means of locomotion is the great specialty of birds. Wing-feathers are those which grow upon

the *pteryla alaris*. They are of two main sorts: the *flight-feathers* proper, or long stiff quills, collectively called *remiges* (Lat. *remex*, pl. *remiges*, rowers); and the smaller, weaker feathers overlying them, and hence called *coverts*, or *tectrices* (Lat. *tectrix*, pl. *tectrices*, coverers). To these may be added as a third distinct group, the *bastard quills*, which constitute the

Alula, or Ala Spuria (Lat. *alula*, little wing, diminutive of *ala*, wing; *spuria*, spurious, bastard). The "little wing" is simply the small parcel of feathers which grow upon the "thumb" (see Fig. 27, *d* 2; 29, *d* and *k*; 30, *al*). Highly significant as these may be in a morphological point of view, as representing what this part of the wing may have been in early times, they are so much reduced in modern birds as to be of little account in practical ornithology. In fact, the unpractised student may fail to recognise them at first. They form a small packet on the fore outer border of the pinion near the carpal angle, and lie smoothly upon the upper surface of the wing, strengthening and finishing off what would be otherwise a weak spot in the contour of the wing-border. It is quite easy, on recognising them, to lift them collectively a little away from the other feathers, owing to the mobility of thumb. In fact, they are sometimes quite obtrusive, when faulty taxidermy has discomposed them. They are not often conspicuously modified either in size or colour. In a few birds (*e.g. Cathartes*), a *claw* will be found at the end of the joint which bears them. (The student must be careful to discriminate between the use of the word *spurious* in the present connection and its application to a rudimentary condition of the first *remex*; see p. 167.) The

Wing-Coverts overlie the bases of the large quills on both the upper and under surfaces of the wing. They are therefore conveniently divided into an *upper* set (*tectrices superiores*) and an under set (*tect. inferiores*). The former are so much more conspicuous than the latter that they are always understood when "upper" is not specified. The latter are sometimes collectively called "the lining of the wings." Coverts include all the *small* feathers of the wings excepting the bastard quills; they extend a varying distance along the bases of the flight-feathers. The ordinary disposition and division of the upper coverts is as follows:—One set, rather long and stiffish, grow upon the pinion, and are close-pressed upon the bases of the outer nine or ten remiges, covering these large feathers about as far as their structure is plumulaceous. These are the *upper primary coverts*, or coverts of the primaries (Fig 30, *pc*); they are ordinarily the least conspicuous of any. All the rest of the upper coverts are *secondary*; they spring mostly from the forearm. These are considered in three groups or *rows*. The *greater upper secondary coverts*, called simply the "greater coverts"

(*tectrices majores*, Fig. 30, *gsc*), are the first, outermost, longest row, reaching nearest the tips of the flight-feathers; they overlie the bases of nearly all the remiges, excepting the first nine or ten. The *median upper secondary coverts*, shortly known as the "middle coverts" (*tectrices mediæ*), are a next row, shorter and therefore less exposed, but still quite evidently forming a special series (Fig. 30, *msc*). It is a common feature of these median coverts that they shingle over each other contrariwise to the way the greater coverts are imbricated, the outer vane of one being under the inner vane of the next outer one. All the rest of the upper secondary coverts, forming several indistinguishable rows, pass under the general name of *lesser coverts* (*tectrices minores;* Fig. 30, *bc*). The greater coverts furnish an excel-

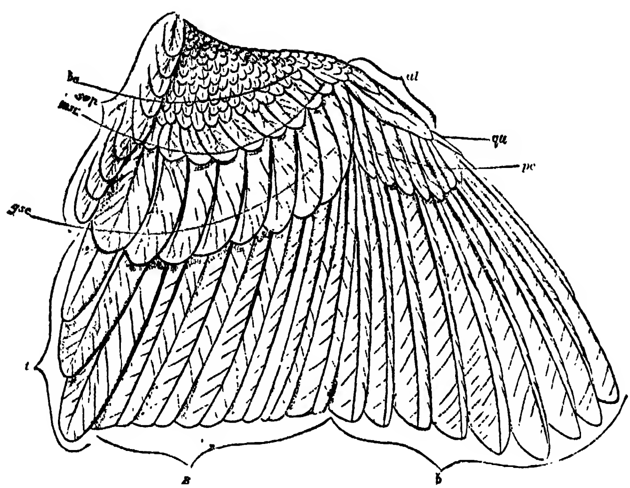


FIG. 30.—Feathers of a sparrow's wing; nat. size. (For explanation see text.)

lent zoological character; for in no *Passeres* are they more than half as long as the remiges they cover, while the reverse is the case in most birds of lower orders. Woodpeckers, however, though non-passerine, have quite short coverts. The *under coverts* have the same general arrangement as the upper; but they are more alike and less distinctly disposed in rows or series; so that for practical purposes they pass under the general name of under wing-coverts, or *lining of the wing.* Since, when the wing is particularly marked on the under side, it is the coverts and not the remiges that are highly or variously coloured, the common expression "wing below," or "under surface of the wing," refers to these coverts more particularly. We should distinguish, however, from the under coverts in

general, the *axillars*, or axillary feathers (Lat. *axilla*, the armpit). These are the innermost feathers lining the wings, lying close to the body; almost always longer, stiffer, narrower, or otherwise peculiarly modified. In ducks, for example, and many of the waders, as snipe and plover, they are remarkably well developed. The colour of the axillaries is the principal distinction between some species of plovers. The

Remiges, or Flight-Feathers (Fig. 30, *b*, *s*, and *t*), give the wing its general character, mainly determining both its size and its shape; they represent most of its surface and of its inner and outer borders, and all of its posterior outline, forming a great expansion, of which the bony and fleshy framework is insignificant in comparison. The shape of the wing is indeed primarily affected by the relative lengths of its bony segments, the upper arm being, in a humming-bird, for example, very short in comparison with the terminal portion of the limb, and in an albatross again, both upper and fore-arm being greatly lengthened; still in any case it is the flight-feathers that mainly determine the contour of the wing, by their absolute degree of development, their lengths proportionately to one another, and their individual shapes. They collectively form a thin, elastic, flattened surface for striking the air, quite firm along the front border where the bone and muscle lie, thence growing more mobile and resilient toward the posterior border and along the outer edge. Such surface may be quite flat, as in such birds as cut the air with long, pointed wings, like oar-blades; but it is generally a little concave underneath, and correspondingly convex above; such arching or vaulting of the wing-surface being usually associated with a short, broad, rounded wing, as in the gallinaceous tribe, and being least in birds which have the thinnest and sharpest wings. Corresponding differences in the mode of flight result. The short, rounded wing confers a powerful though laboured flight for short distances, usually accompanied by a whirring noise resulting from the rapidity of the wing-beats; birds that fly thus are almost always thickset and heavy. The long, pointed wing gives a noiseless, airy, skimming flight, indefinitely prolonged, and accomplished with more deliberate wing-beats; birds of this style of wing are generally trim and elegant. These, of course, are merely generalisations of the extremes of modes of flight, mixed and gradated in every degree in actual bird-life. Thus the humming-bird, which has sharp, thin wings, whirs them fastest of all birds,—so rapidly that the eye cannot follow the strokes, merely perceiving a haze about the bird while the ear hears the buzzing. The combination of acuteness and concavo-convexity is a remarkably strong one, conferring a rapid, vigorous, whistling flight, as that of a duck or pigeon, or the splendid hurtling of a falcon. An ample wing, as

one both long and broad without being pointed is called, is well displayed by such birds as herons, ibises, and cranes; the flight may be strong and sustained, but is rather slow and heavy. The longest-winged birds are found among the swimmers, particularly the pelagic family of the petrels, and some of the whole-webbed order, as pelicans, particularly the frigate-pelican.' The last-named, *Tachypetes aquilus*, has perhaps the longest wings for its bulk of body of any bird whatever, as well as the shortest feet. The American vultures are likewise of great alar expanse in proportion to their weight. The shortest wings, among birds possessing perfect remiges, occur among the lower swimmers, as auks and divers, and among some of the *Gallinæ*. The great auk is, or was, perhaps the only flightless bird with well-formed flight-feathers, only too small to subserve their usual purpose; though certain South American ducks are said to be in similar predicament. In the penguins, the whole wing-structure is degraded, and the remiges abort in scale-like feathers, the wings being reduced to fins both in form and function. The whole of the existing *Ratitæ* or struthious birds, as the ostrich, cassowary, and emeu, have rudimentary or very imperfect wings, as was the case with the Cretaceous *Hesperornis*; but the contemporary of the latter, *Ichthyornis*, and the still more ancient *Archæopteryx*, appear both to have had excellent ones.

The disposition of the remiges in their mutual relations is very noteworthy. They have a rigid hollow barrel of great resistant powers, considering the amount of substance,—just like the cylindrical stem of the cereal plant; a stout, solid, highly-elastic shaft; the outer web narrower than the inner, with its barbs set at a more acute angle upon the shaft. Any one of these stiffer outer vanes *overlies* the broader and more yielding inner vane of the next outer feather, which, on receiving the impact of air from below, resists as it were with the strength of a second shaft superimposed. Though the "way of an eagle in the air" was a mystery to the wise man of old, the mechanics of ordinary flight are now better understood. But the sailing of some birds for an indefinite length of time, up as well as down, without visible motion of the wings, and without reference to the wind, remains an enigma. The flight of the albatross and turkey vulture, I venture to affirm, is not yet explained. The riddle of The Wing will be read when we know how the archsaurian escaped from ilus to æther.

The number of true remiges ranges from about sixteen, as in a humming-bird, to upwards of fifty, as in the albatross. Their shape is quite uniform, minor details aside. They are the stiffest, strongest, most perfectly *pennaceous* of feathers, without evident hyporhachis, if any. They are generally *lanceolate*, that is, tapering regularly and gradually to an obtuse point, though not infrequently

more parallel-sided, especially those of the secondary and tertiary series. Either or both webs may be incised toward the end; that is, more or less abruptly narrowed; this is called *emargination*; their ends may be transversely or obliquely truncate, or nicked in various ways. In a few birds, apparently for purposes of sexual ornamentation, they are developed in bizarre shapes of beauty, with evident decrease of utility as flight-feathers. Those of the ostrich and penguin tribes share the peculiarities of the general plumage of these extraordinary birds. Remiges are divided into three classes or series, according to where they grow upon the limb, whether upon the hand, the forearm, or the upper arm. In this distinction is involved one of the most important considerations of practical ornithology, of which the student must make himself master. The three classes of quill-feathers are: 1, the *primaries*; 2, the *secondaries*; 3, the *tertiaries*.

The Primaries (Fig. 30, *b*) are those remiges which grow upon the pinion, or wrist-, hand-, and finger-bones collectively (Fig. 27, *C* to *D*). Whatever the total number of the remiges may be, *in nearly all birds with true remiges the Primaries are either* NINE OR TEN *in number*. The humming-bird with sixteen remiges, the albatross with fifty or more, each has ten primaries. The grebes and a few other birds are said to have eleven primaries: if this be so, it is highly exceptional. No instance of a higher number than this is known to me. Again, it is only among the highest *Passeres* that the number nine is found, the *Oscines* having indifferently nine or ten. In a good many *Oscines*, rated as nine-primaried, there are actually ten, though the outermost is so rudimentary, and even out of alignment with the developed primaries, that it is not counted as one of them. Among *Oscines*, just this difference of one evident and unquestionable primary more or fewer forms one of the best distinctions between the families of that suborder. So the tenth feather in a bird's wing, counting from the outside, becomes a crucial test in many cases; for, if it be last primary, the bird is one thing; if it be first secondary, the bird is another. In such cases the necessity, therefore, of determining exactly which it is becomes evident. Of course it is always possible to settle the question by striking at the roots of the remiges and seeing how many are seated on the pinion; but this generally involves some defacing of the specimen, and there is usually an easier way of determining. Hold the wing half-spread; then, in most *Oscines*, the primaries come sloping down on one side, and the secondaries similarly on the other, to form where they meet a reëntrant angle in the general contour of the posterior border of the wing; the feather that occupies this notch is the one we are after, and unluckily it is sometimes last primary, sometimes first secondary.

But observe that primaries are, so to speak, *self-asserting*, *emphatic*, *italicised*, remiges, stiff, strong, and obstinate; while secondaries are *retiring*, *whispering*, *in brevier*, limber, weak, and yielding. Their different character is almost always shown by something in their shape or texture which the student will soon learn to recognise, though it cannot well be described. Let him examine Fig. 30, where *b* marks the nine primaries of a sparrow's wing, and *s* indicates the secondaries; he will see a difference at once. The primaries express themselves, though with diminishing emphasis, to the last one; then the secondaries begin to tell a different tale. The condition of the first primary, whether *spurious* or not, is often of great help in this determination. The first primary is called "spurious" when it is very short—say one-third, or less, as long as the second, or longest primary. Among *Passeres*, a spurious first primary only occurs in certain ten-primaried *Oscines;* whence it is evident, that to find such short first primary is equivalent to determining the presence of ten primaries, though not to find it does not prove there are only nine; the count should be made in all cases in which the outer primary is more than one-third as long as the next. The difference between nine primaries, and ten with the first spurious, is excellently illustrated among the species of the American *Vireo.* Any thrush, nuthatch, titmouse, or creeper shows a spurious primary to advantage—large enough not to be overlooked, small enough not to be mistaken.

The Secondaries (Fig. 30, *s*) are those remiges which are seated on the forearm (Fig. 27, *B* to *C*). They vary in number from six to forty or more. They have the peculiarity of being attached to one of the bones of the forearm, the *ulna.* If an ulna be examined closely, there will be seen a row of little points showing the attachment; such are indicated in Fig. 27, along *ul*, and in Fig. 31. The secondaries present no points necessary to dwell upon here, after what has been said of the primaries. They are enormously developed in the Argus pheasant, and have curious shapes in some other exotic birds. They are often long enough to cover the primaries completely when the wing is closed, as in grebes; on the other hand, they are extremely short in the swifts and humming-birds.

FIG. 31.—Ulna of *Colaptes mexicanus*, showing points of attachment of the secondaries. (Dr. R. W. Shufeldt, U.S.A.)

The Tertiaries (Fig. 30, *t*) are properly the remiges which grow upon the upper arm, *humerus.* But such feathers are not very evident in most birds, and the two or three innermost secondaries, growing upon the very elbow, and commonly different from the rest in form or colour, pass under the name of "tertiaries." Again, in some

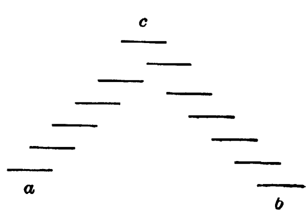
Claws and Spurs are found upon the pinion. Claws have been already noticed (p. 160). They are properly so called, being horny growths comparable in every way to those upon the ends of the toes, like the claws of beasts, or human nails. A *spur* (Lat. *calcar*), however, is something different, though of the same horny texture, since it does not terminate a digital phalanx, but is off-set from the side of the hand. It is exactly like the spur on the leg of a fowl, which obviously is not a claw. The spur-winged goose (*Plectropterus*), pigeon (*Didunculus*), plovers (*Chettusia*, etc.), the Jaçanas (*Parra*), and the doubly-spurred screamer (*Palamedea*), afford examples of such outgrowths. (See Fig. 53 *ter*.)

changed all that *distichous* arrangement since when the *Archæopteryx* was steered with such a rudder through the scenes of its Jurassic life. Now the true separate *coccygeal* bones are few, generally about nine in number, and so short and stunted that they do not project beyond the general plumage—in fact, scarcely beyond the border of the pelvis. Anteriorly, within the bony basin of the pelvis, there are several vertebræ, which, fusing together and with the true *sacrum*, are termed *urosacral* or false tail-bones. To these succeed the true caudal vertebræ, movable upon each other and upon the urosacrum. The last one of these, abruptly larger than the rest, and of peculiar shape, bears all the large tail-feathers, which radiate from it like the blades of a fan. The true caudal vertebræ collectively form the *coccyx* (Gr. κόκκυξ, *kokkux*, a cuckoo; from fancied resemblance of the human tail-bones to a cuckoo's bill; Fig. 56, *clv*); the enlarged terminal one is the *vomer* (Lat. *vomer*, a ploughshare, from its shape; not to be confused with a bone of the skull of same name) or *pygostyle* (Gr. πυγή, *puge*, rump, and στῦλος, *stulos*, a stake, pale; Fig. 56, *py*). The pygostyle, however, is a compound bone, consisting of several stunted coccygeal vertebræ fused in one. The bones are moved by appropriate muscles, and upon the surface is seated the elæodochon (p. 129). The whole bony and muscular affair is familiar to every one as the "pope's nose" of the Christmas turkey; it is a bird's real tail, of which the feathers are merely appendages. In descriptive ornithology, however, the anatomical parts are ignored, the word "tail" having reference solely to the feathers. These, like those of the wings, are of two sorts: the coverts or *tectrices*, and the rudders or *rectrices* (Lat. *rectrix*, pl. *rectrices*, a ruler, guider; because they seem to steer the bird's flight); corresponding exactly to the coverts and remiges of the wings. The

Tail-Coverts are the numerous comparatively small and weak feathers which overlie and underlie the rectrices, covering their bases and extending a variable distance toward their ends, contributing to the firmness and symmetry of the tail. They pass smoothly out from the body, by gradual lengthening, there being seldom, if ever, any obvious outward distinction between them and feathers of the rump and belly; but they belong to the *pteryla caudalis* (p. 131). The natural division of the coverts is into an *upper* and *under* set (*tectrices superiores, tectrices inferiores*). The

inferior coverts are the best distinguished from the general plumage, the anus generally dividing off these "vent-feathers," as they are sometimes called. It is to the bundle of under tail-coverts, behind the vent, that the term *crissum* is most properly applied. Neither set is ever entirely wanting; but one or the other, particularly the upper one, may be very short, as in a cormorant, or duck of the genus *Erismatura,* exposing the quills almost to their bases. While the upper coverts are usually shorter and fewer than the under ones, reaching less than half-way to the end of the tail, they sometimes take on extraordinary development and form the bird's chiefest ornament. The gorgeous, iridescent, argus-eyed train of the peacock consists of enormous tectrices, not rectrices; the elegant plumes of the paradise trogon, *Pharomacrus mocinno,* several times longer than the bird itself, are likewise coverts. Occasionally, a pair of coverts lengthens and stiffens, and then resembles true tail-feathers, as in the ptarmigan (*Lagopus*). The crissal feathers are more uniform in development; they ordinarily form a compact, definite bundle, as well shown in a duck, where they reach about to the end of the tail. In some of the storks, they become plumes of considerable pretensions known as *marabous;* and in the wonderful humming-bird, *Loddigesia mirabilis,* the middle pair stiffens to resemble rectrices and projects far beyond the true tail. The

Rectrices, Rudders, or true tail-feathers, like the remiges or rowers, are usually stiff, well-pronounced feathers, pennaceous to the very base of the vexilla, without after-shafts, as a rule, and with the outer web narrower than the other in most cases. They are always *in pairs;* that is, there is an equal number of feathers on the right and left half of the tail; and their number, consequently, is an even one. The exceptions to this rule are so few and irregular, and then only among birds with the higher numbers of rectrices, that such are probably to be regarded as mere anomalies, from accidental arrest of a feather. They are imbricated over each other in this wise: the central pair are highest, lying with *both* their webs over the next feather on either side, the inner web of one of these middle feathers indifferently underlying or overlying that of the other; all thus successively overlying the next outer one so that they would form a pyramid were they thick instead of being so flat. The arrangement is perceived at once in the accompanying diagram; where it will be seen, also, that *spreading* the tail is the divergence of *a* from *b*, while closing the tail is bringing *a* and *b* together under *c*. The motion is effected by certain muscles



that draw on either side upon the bases of the quills collectively; they are the same that pull the whole tail to one side or the other, acting like the tiller-ropes of a boat's rudder. The *general*

Shape of a Rectrix is shown in Fig. 23. Such a feather is ordinarily straight, somewhat clubbed or oblong, widening a little, regularly and gradually toward the tip, where it is gently rounded

FIG. 32.—The Lyre-bird of Australia, *Menura superba*, to show the unique *lyrate* shape of the tail.

off. But the departures from such shape, or any that could be assumed as a standard, are numberless, and in some cases extreme. In fact, none of a bird's feathers are more variable than those of the tail; it is impossible to specify all the shapes they assume. While most are straight, some are curved—and the curvature may be to or from the middle line of the body, in the horizontal plane, or up and down, in the vertical plane. Some shapes have received

particular names. A rectrix, broad to the very tip, and there cut squarely off, is said to be *truncate;* one such cut obliquely off is *incised*, especially when, as often happens, the outline of the cut-off is concave. A *linear* rectrix is very narrow, with parallel sides; a *lanceolate* one is broader at the base, thence tapering regularly and gradually to the tip. A notably pointed rectrix is said to be *acute;* when the pointing is produced by abrupt contraction near the tip, as in most woodpeckers, the feather is *acuminate.* A very long and slender, more or less linear feather is called *filamentous*, as the lateral pair of a barn-swallow or most sea-swallows. The vanes sometimes enlarge abruptly at the end, forming a spoon-shaped or *spatulate* feather; or such a spoon may result from narrowing of the vanes near the end, or their entire absence, as in the "racket" of a saw-bill (*Momotus*). The vanes are sometimes wavy as if crimped; *Plotus* is a fine example of this. Sometimes the vanes are entirely loosened, the barbs being remote from each other, as in the exotic genus *Stipiturus*, and some parts of the wonderful caudal appendage of the male lyre-bird (*Menura superba*, Fig. 32). When the rhachis projects beyond the vanes, the feather is *spinose*, or better, *mucronate* (Lat. *mucro*, a pricker), as excellently shown in a chimney-swift of the genus *Chætura.* A pair of feathers abruptly extending far beyond the others are called *long-exserted*, after the analogous use of the term in botany. Tail-feathers also differ much in their consistency, from the softest and weakest, not well distinguished from coverts, to such stiff and rugged props as the woodpeckers possess. They are downy and very rudimentary in a few birds, notably all the grebes, *Podicipedidæ*, which are commonly said to have no tail. The tinamous of South America (*Dromæognathæ*) are also very closely docked. The

Typical Number of Rectrices is *twelve.* This holds in the great majority of birds. It is so uniform throughout the great group Oscines, that the rare exceptions seem perfectly anomalous. In the other group of *Passeres* (*Clamatores*) it is usually twelve, sometimes ten. Ten is the rule among *Picariæ*, though many have twelve, a very few only eight, as in the genus *Crotophaga.* The whole of the woodpeckers (*Picidæ*) have *apparently* ten; but really twelve, of which the outer one on each side is spurious, very small, and hidden between the bases of the second and third feathers. Birds of prey (*Raptores*) have usually twelve. In pigeons the rule is twelve or fourteen; but sixteen are found in some, and twenty in one case. In birds below these, the number increases directly; there are often or usually more than twelve in the grouse family, and there may be sixteen, eighteen, or twenty, as among American genera of *Tetraonidæ.* Wading birds, often having but twelve, furnish instances of as many as twenty. Those swimming birds with large well-formed tails, as the *Longipennes*, and some *Anatidæ*

have the fewest, as twelve, sometimes fourteen, rarely sixteen; those with short soft tails have the most, as sixteen to twenty-four. Among the penguins there are thirty-two or more. The *Archæopteryx* appears to have had forty,—a pair to each free caudal vertebra; and this may be considered the prototypic relation between the bones and feathers of the tail. The

Typical Shape of the Tail, as a whole, is the *fan*. The modifications of form, however, which are greater and more varied than those of the wing, are susceptible of better definition, and many of them have received special names. Taking the simplest case, where the rectrices are all of the same length, we have what is called the *even, square*, or *truncate* tail. The other forms depart from this mainly by shortening or lengthening of certain feathers. A tail nearly or quite even may have the two central feathers long-exserted, as seen in the jaegers (*Stercorarius*), and tropic-birds (*Phaëthon*). The most frequent departure from the even shape results from gradual shortening of successive rectrices from the middle to the outer ones. This is called, in general, *gradation* or *graduation* (Lat. *gradus*, a step); such shortening may be to any degree. More precisely, graduation means shortening of each successive feather to the same extent,—say, each half an inch shorter than the next; but such exactitude is not often expressed. When the feathers shorten by more and more, we have the true *rounded* tail, probably the commonest form among birds; thus, the gradation between the middle and next pair may be just appreciable, and then increase regularly to an inch between the next and the lateral feather. The opposite gradation, by less and less shortening, gives the wedge-shaped or *cuneate* (Lat. *cuneus*, a wedge) tail; it is well shown by the magpie (*Pica*) in which, as in many other birds, the middle feathers would be called long-exserted were the rest all as short as the outer one is. A cuneate tail, especially if the feathers be narrow and lanceolate, is also called *acute*, or pointed, as in the sprig-tailed duck (*Dafila*) or sharp-tailed grouse (*Pediœcetes*). The generic opposite of the gradated is the *forked* tail; in which the lateral feathers successively increase in length from the middle to the outermost pair. The least appreciable forking is called *emargination*, and a tail thus shaped is said to be *emarginate;* when it is better marked, as, for instance, an inch of forking in a tail six inches long, the tail is truly *forked* or *furcate* (Lat. *furca*, a fork). But the degrees of furcation, like those of gradation, are so insensibly varied, that qualified expressions are usual; as, "slightly forked," "deeply forked." Deep furcation is usually accompanied by more or less narrowing or filamentous elongation of the lateral pair of rectrices, as in the barn swallows (*Hirundo*) and most of the sea-swallows (*Sterna*). An advisable term to express such an ex-

treme furcation is *forficate* (Lat. *forfex*, scissors), when the depth of the fork is at least equal to the length of the shortest feathers; it occurs among the birds last named, in the species of the tyrannine genus *Milvulus*, and elsewhere. *Double-forked* and *double-rounded* tails are not uncommon; they result from combination of both opposite gradations, in this way: The middle feathers being of a certain length, the next two or three pairs progressively increasing in length, and the rest successively decreasing, the tail is evidently forked centrally, rounded externally, which is the double-rounded form, each half of the tail being rounded; it is shown in the genera *Myiadestes* and *Anous*. Now if with middle feathers as before, the next pair or two decrease in length, and then the rest increase to the outermost, we have the double-forked, a common style among sandpipers, as if each half of the tail were forked. But in such case, the forking is slight, merely emargination, being little more

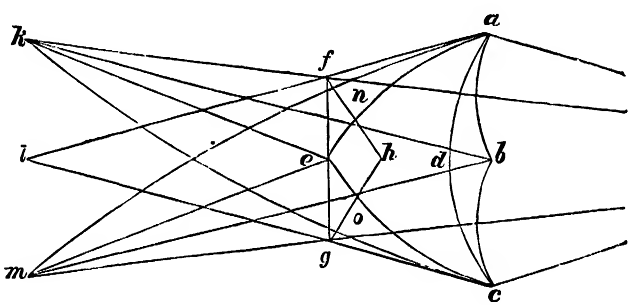


FIG. 33.—Diagram of shapes of tail. *adc*, rounded; *aec*, gradate; *aic*, cuneate-gradate; *alc*, cuneate; *abc*, double-rounded; *feg*, square; *fhg*, emarginate; *fneog*, double-emarginate; *kim*, forked; *kem*, deeply forked; *kbm*, forficate.

than protrusion of the middle pair of feathers in an otherwise lightly forked tail; and in the double-rounded form the gradation is seldom if ever great.

I should also allude to shapes of tail resulting from the relative positions of the feathers. Prominent among these is the *complicate* or *folded* tail of the barn-yard fowl, and others of the *Phasianidæ*,—a very familiar but not common form. It is only retained while the tail is closed and cocked up,—for when it is lowered and spread in flight it flattens out. The males of some of the African whydah birds (*Viduinæ*) have remarkably large and long tails of somewhat similar character. The opposite disposition of the feathers is seen to some extent in crow-blackbirds (*Quiscalus*), where the lateral feathers slant upward from the lowermost central pair, like the sides of a boat from its keel; this is the *scaphoid* (Gr. σκάφη, a boat) or *carinate* (Lat. *carina*, a keel) tail. The American "boat-

tailed" grackle has been so named on this account. One of the most beautiful and wonderful of all the shapes of the tail is illustrated by the male of the lyre-bird (*Menura superba*, Fig. 32), in which the feathers are anomalous both in shape and in texture, and the resulting form of the whole is unique. It should be remembered that, to determine the shape, the tail should be *nearly* closed; for spreading will make a square tail round, an emarginate one square, etc. I give a diagram of the principal forms (Fig. 33).

IV. THE FEET.

The Hind Limbs, in all birds, are organised for progression—all can walk, run, or hop on land, though the power to do so is very slight in some of the lower swimming birds, as loons and grebes, and certain of the lower perching birds, as hummers, swifts, goatsuckers, and kingfishers. They are specially fitted for perching on trees, bushes, and other supports requiring to be grasped, in the great majority of birds, as throughout the *Passeres*, *Picariæ*, *Accipitres*, *Columbæ*, and, in fact, many water-birds; there being few forms, mainly found among three-toed birds, or those in which the hind toe is short, weak, and elevated, in which the extremity of the limb has not decided grasping power. The limb becomes a paddle for swimming either on or in the water in many cases. In not a few, as parrots and birds of prey, the foot is serviceable as a hand. Those kinds of birds which live in trees and bushes habitually progress, even when on level ground, in a series of hops, or rather leaps, both feet being moved together: in all the lower birds, however, the feet move one after the other, as in ordinary walking or running. The modifications of the hind limb are more numerous, more diverse, and more important in their bearing on classification, than those of either bill, wing, or tail; their study is consequently a matter of special interest.

Their Bony Framework (Fig. 34).—Beginning at the hip-joint, and ending at the extremities of the several toes, the skeleton of the hind limb consists in the vast majority of adult birds of *twenty* bones. This is the typical and nearly the average number; birds scarcely ever have more, and the principal lessenings of the number result from the absence of one or two toes, or a slight reduction in the number of the joints of some toes, or absence of the knee-cap. Of the normal twenty, fourteen are bones of the toes; one is an incomplete bone connecting the hind toe with the foot; one is the knee-cap, and four are the principal bones of the thigh (1), leg (2), and foot (1). The first or uppermost is the thigh-bone or *femur* (Lat. *femur*; adjective, *femoral*), *fm*, from hip to knee, *A* to *B* in the figure. It is a rather short, quite stout, cylindrical bone, enlarged

above and below. Above it has a globular head, *a*, standing off obliquely from the shaft, received in the *acetabulum* (Lat. *acetabulum*, a kind of receptacle) or socket of the hip, and a prominent shoulder or *trochanter*, which abuts against the brim of the acetabulum. Below, it expands into two *condyles* (Gr. κόνδυλος, *kondulos*, a knob),

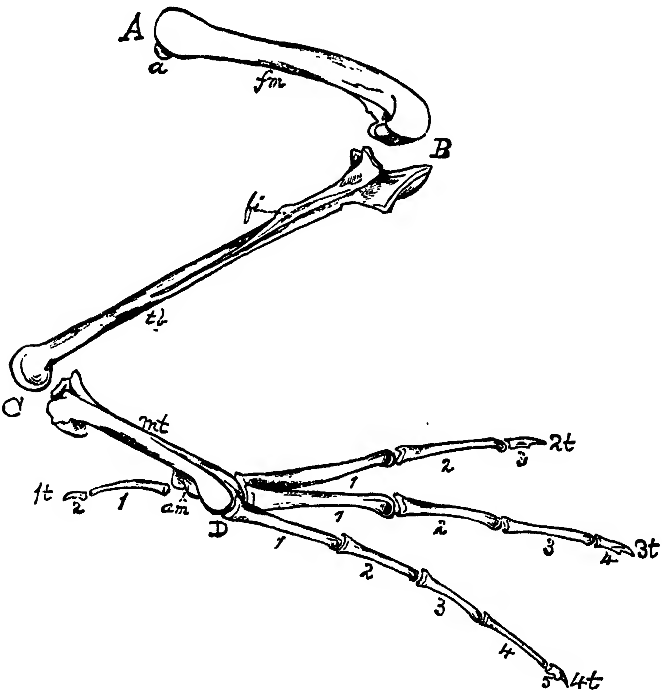


FIG. 34.—Bones of a bird's right hind limb: from a duck, *Clangula islandica*, ⅔ nat. size; Dr. R.W. Shufeldt, U.S.A. *A*, hip; *B*, knee; *C*, heel or ankle-joint, *suffrago*; *D*, bases of toes. *A* to *B*, thigh or "second joint"; *B* to *C*, crus, leg proper, "drumstick," often wrongly called "thigh"; *C* to *D*, metatarsus, foot proper, corresponding to our instep, or foot from ankle to bases of toes; in descriptive ornithology *the tarsus*; often called "shank." From *D* outward are the toes or digits. *fm*, femur; *tb*, tibia, principal (inner) bone of leg; *fi*, fibula, lesser (outer) bone of leg; *mt*, principal metatarsal bone, consisting chiefly of three fused metatarsal bones; *am*, accessory metatarsal, bearing 1*t*, first or hind toe, with two joints; 2*t*, second toe, with three joints; 3*t*, third toe, with four joints; 4*t*, fourth toe, with five joints. At *C* there are in the embryo some small tarsal bones, not shown in the figure, uniting in part with the tibia, which is therefore a *tibio-tarsus*, in part with the metatarsus, which is therefore a *tarso-metatarsus*; the ankle-joint being therefore between two rows of tarsal bones, not, as it appears to be, directly between tibia and metatarsus.

for articulation with both the bones it meets at the knee. It is the same bone as the femur of a quadruped or of man, and corresponds to the *humerus* of the wing. In the knee-joint, many or most birds have a small ossicle, and a few have two such bony nodules, not shown in this figure, but nearly in the position of the letter *B*; it

is the knee-pan or knee-cap, *patella* (Lat. *patella*). The thigh is the first *segment* of the limb; the next segment is the leg proper, or *crus* (Lat. *crus*, the shin; adjective, *crural*), *B* to *C* in the figure, or from knee to heel. This segment is occupied by two bones, the *tibia* (Lat. *tibia*, a tube, trumpet), *tb*, and *fibula* (Lat. *fibula*, a splint, clasp), *fi*. Of these the tibia is the principal, larger, inner bone, running quite to the heel; the fibula is smaller, and (with rare exceptions, as in some of the penguins) only runs part way down the outside of the tibia as a slender pointed spike, close pressed against or even partly fused with the shaft of the tibia. Above, at the knee, both bones articulate with the femur; the tibia with both the femoral condyles, the fibula only with the outer condyle. Above, the tibia has an irregularly expanded head or *cnemial* process (Gr. κνήμη, *kneme*), which in some birds, as loons, runs high up in front above the knee-joint. Below, the tibia alone forms the ankle-joint, *C*, by articulating with the next bone. For this purpose it ends in an enlarged *trochlear* (Gr. τροχαλία), or pulley-like surface, presenting a little forward as well as downward, above which, in many birds, there is a little bony bridge beneath which tendons passing to the foot are confined. This finishes the leg, consisting of thigh, *A B*, and leg proper, *B C*, bringing us to the ankle-joint at the heel, *C*.

Now a bird's legs, unlike ours, are not separate from the body from the hip downward; but, for a variable distance, are enclosed within the general integument of the body. The freedom of the limb is greatest among the high perching birds, and especially the *Raptores*, which use the feet like hands, and least among the lowest swimmers. The range of variation, from greatest freedom to most extensive enclosure of the limb, is from a little above *B* nearly to *C*—the latter in the case of a loon, grebe, or penguin. In no bird is the knee, *B*, seen outside the general contour of the plumage: it must be looked or felt for among the feathers, and in most prepared skins will not be found at all, the femur having been removed. It is a point of little practical consequence, though bearing upon the generalisation just made. The first *joint*, or bending of the limb, that appears beyond a bird's plumage is the *heel*, or *suffrago*, *C*; and this is what, in loose popular parlance, is called "knee," upon the same erroneous notions that make people call the wrist of a horse's fore-leg "knee." People also call a bird's *crus* or leg proper, *B* to *C*, the "thigh," and disregard the true thigh altogether. This confusion is inexcusable; any one, even without the slightest anatomical knowledge, can tell knee from heel at a glance, whatever their respective positions relative to the body. *Knee* is at junction of thigh and leg proper; it always bends forward; *heel* is at junction of leg with foot, and always bends backward. This is as true of a

bird, which is *digitigrade*, that is, walks on its toes with its heels in the air, as it is of a man, who is *plantigrade*, that is, walks on the whole sole of the foot, with the heel down to the ground. In a carver's language, the thigh is the "second joint" (from below); the leg is the "drumstick"; the rest of a fowl's hind limb does not usually come to table, having no flesh upon it.

Before proceeding to the next segment of the limb, I must dwell upon the ankle-joint, situated at the heel,—the point *C*,—corresponding to the carpal angle or bend of the wing, *C*, in Fig. 27. There we found, in adult birds, two small carpal bones, or bones of the wrist proper; and noted the presence in the embryo of several other carpals (Fig. 29), which early fuse with the metacarpus. Just so in the ankle, there are in embryonic life several *tarsal* bones, or bones of the *tarsus* (Lat. *tarsus*, the ankle); *all* of which, however, soon disappear, so that there appears to be no tarsus, or collection of little bones between the tibia and the next segment of the limb, the *metatarsus*. An upper tarsal bone, or series of tarsal bones, fuses with the lower end of the tibia, making this leg-bone really a *tibio-tarsus;* and similarly, a lower bone or set of bones fuses with the upper end of the metatarsus, making this bone a *tarso-metatarsus.* So there are left no free bones in the ankle-joint, which thus appears to be immediately between the leg-bone and the principal foot-bone; but which is nevertheless really between two series of tarsal bones, the separateness or identity of which has been lost.[1]

The next segment of the limb, *C* to *D*, or the foot proper, is represented by the principal *metatarsal* bone, *mt.* This corresponds to the human *instep* or arch of the foot, nearly from the ankle-joint quite to the roots of the toes. The metatarsal bone, like the metacarpal of the hand, which it represents in the foot, is a compound

[1] The exact homologues of a bird's vanishing tarsal bones are still questioned. Gegenbaur showed the so-called epiphysis or shoe of bone at the foot of the tibia, and the similar cap of bone on the head of the principal metatarsal bone, to be true tarsal elements. Morse went further, showing the tibial epiphysis, or upper tarsal bone of Gegenbaur, to be really two bones, which he held to correspond with the tibiale and fibulare, or *astragalus* and *calcaneum* of mammals; these subsequently combining to form the single upper tarsal bone of Gegenbaur, and finally becoming anchylosed with the tibia to form the bitrochlear condylar surface so characteristic of the tibia of *Aves.* The distal tarsal ossicle he believed to be the *centrale* of reptiles. Wyman discovered the so-called "process of the astragalus" to have a distinct ossification, and Morse interpreted it as the *intermedium* of reptiles. Later views, however, as of Huxley and Parker, limit the tibial epiphysis to the *astragalus* alone of mammals. If these opinions be correct, other tarsal elements (more than one) are to be looked for in the epiphysis of the metatarsus. Whatever the final determination of these obscure points may be, it is certain that, as said in the text above, the lower end of a bird's tibia and the upper end of a bird's metatarsus include true tarsal elements, just as the upper end of the metacarpus includes carpal elements; and that a bird's ankle-joint is *not* tibio-tarsal or between leg-bone and foot-bones, as in mammals, but between proximal and distal series of tarsal bones, and therefore *medio*-tarsal, as in reptiles.

one. Besides including the evanescent tarsal element or elements already specified, it consists of *three* metatarsal bones consolidated in one, just as the metacarpal is tripartite. Among recent birds, the three are partly distinct only in the penguins; but in all, excepting ostriches, the original distinction is indicated by three prongs or stumps at the lower end of the bone, forming as many articular surfaces for the three anterior toes. The other toe most birds possess, the hind toe, is hinged upon the metatarsus in a different way, by means of a small separate metatarsal bone, quite imperfect; this is the *accessory metatarsal, am.* It is situated near the lower end toward the inner side of the principal metatarsal

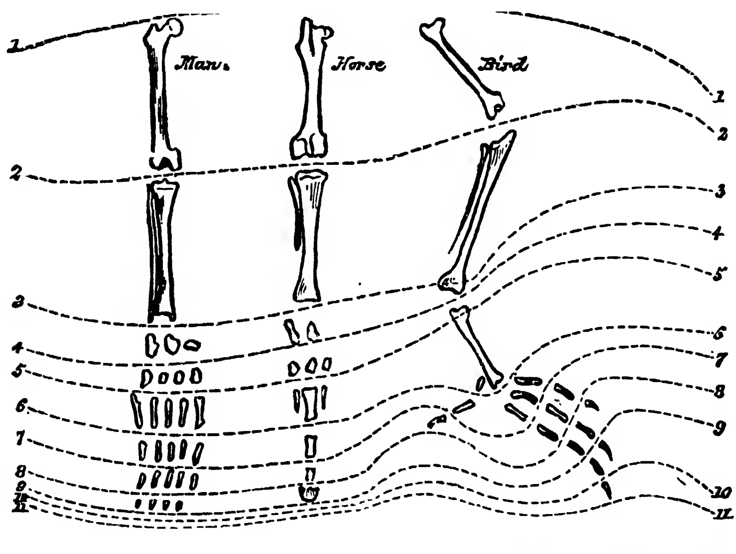


FIG. 34 *bis.*—Diagram of corresponding segments of hind limbs of man, horse, and bird. The lines 1-11 are *isotomes*, cutting the limbs into morphologically equal parts, or *isomeres.*

bone, and is of various shapes and sizes; it has no true jointing with the latter, but is simply pressed close upon it, much as the fibula is applied to the tibia, or partly soldered with it. Above, it is defective; below, it bears a good facet for articulation with the hind toe. In spite of anatomical proprieties, the metatarsal part of a bird's foot—from heel to base of toes—from *C* to *D*, is in ordinary descriptive ornithology invariably called "*The Tarsus*"; a wrong name, but one so firmly established that it would be finical and futile to attempt to substitute the correct name. In the ordinary attitude of most birds, it is held more or less upright, and seems to be rather "leg" than a part of the "foot." It is vulgarly called

"the shank." These points must be ingrained in the student's mind to prevent confusion (Fig. 34 *bis*).

The *digits* of the foot, or *toes*, upon which alone most birds walk or perch, consist of certain numbers of small bones placed end to end, all jointed upon one another, and the basal or proximal ones of each toe separately jointed either with the principal or the accessory metatarsal bone. Like those of the fingers, these bones are called *phalanges* (Lat. *phalanx*, a rank or series) or *internodes* (because coming between any two joints or nodes of the toes). The furthermost one of each almost invariably bears a nail or claw (*unguis*). The phalanges are of various relative lengths, and of a variable number in the same or different toes. But all these points, being matters of descriptive ornithology rather than of anatomy proper, are fully treated beyond, as is also the special horny or leathery covering of the feet usually existing from the point *C* outward. We may here glance at the

Mechanism of these Bones.—The hip is a ball-and-socket joint, permitting roundabout as well as fore-and-aft movements of the whole limb, though more restricted than the shoulder-joint. The knee is usually a strict *ginglymus* (Gr. γίγγλυμος, *gigglumos*, hinge) or hinge-joint, allowing only backward and forward motion; and so constructed that the forward movement of the leg is never carried beyond a right line with the femur, while the backward is so extensive that the leg may be quite doubled under the thigh. In some birds there is a slight rotatory motion at the knee, very evident in certain swimmers, by which the foot is thrown outward, so that the broad webbed toes may not "interfere." The heel or ankle-joint is a strict hinge; its bendings are just the reverse of those of the knee; for the foot cannot pass back of a right line with the leg, but can come forward till the toes nearly touch the front of the knee. In some birds the details of structure are such that, with the assistance of certain muscles, the foot is *locked* upon the leg when completely straightened out, so firmly that some little muscular effort is required to overcome the obstacle; birds with this arrangement sleep securely standing on one leg, which is the design of the mechanism. The jointing of the toes with the prongs of the metatarsus is peculiar; for the articular surfaces are so disposed in a certain obliquity, that when the toes are brought forwards, at right angles or thereabouts with the foot, they spread apart from each other automatically in the action, and the diverging toes of the foot thus opened are pressed upon the ground or against the water. When the toes are bent around in the opposite direction, they automatically come together and lie in a bundle more or less parallel with one another, besides being each bent or flexed at their several nodes. This mechanism is best marked in the swimmers, which, for advantageous

use of their webbed toes, must present a broad surface to the water in giving the backward stroke, and bring the foot forward with the toes closed, presenting only an edge to the water,—on the principle of the feathering of oars in rowing. It is carried to an extreme in a loon, where, when the foot is closed, the digit marked *2t* in the figure lies below and behind *3t*. It is probably least marked in birds of prey, which give the clutch with their talons spread. The jointings of the individual phalanges of the toes upon one another are simple hinges, permitting motion of extension to a right line or a little beyond in some cases, with very free flexion in the opposite direction. On the whole, the mechanics of a bird's foot are less peculiar than those of the wing, and quite like those of the limbs of a quadruped.

In ordinary hopping, walking, and running, and in perching as well, only the toes rest upon or grasp the support, from *D* to beyond, *C* being more or less vertically over *D*. Such resting of the toes is complete for *2t*, *3t*, *4t* in the figure, or for all the anterior toes; but for the hind toe it varies according to the length and position of that digit, from complete incumbency, like that of the front toes, to mere touching of the tip of that toe, or not even this: the hind toe is then sure to be functionless. But many of the lower birds, such as loons and grebes, cannot stand at all upright on their toes, but rest with the heel (*C*) touching the ground; and in many such cases the tail furnishes additional support, making a tripod with the feet, as in the kangaroo. Such birds might be called *plantigrade* (Lat. *planta*, the sole; *gradus*, a step) in strict anatomical conformity with the quadrupeds so designated. The others are all *digitigrade*, standing or walking on their toes alone. But no birds progress on the ends of their toes, or toe-nails, as hoofed quadrupeds do. A bird's walking or running is the same as ours, so far as the ordinary mechanics of the motions are concerned; but its so-called "hopping" is really leaping, both legs moving at once. Most birds, down to *Columbæ*, leap when on the ground, a mode of progression characteristic of the higher orders; but many of the more terrestrial *Passeres* and *Accipitres* progress by ordinary walking when on the ground, as is invariably the case with parrots, pigeons, gallinaceous birds, and all waders and swimmers.

The student need scarcely be reassured that, whatever their modifications, their relative development, motions, and postures, the several segments of both fore and hind limbs of any vertebrate, quadruped or biped, feathered or featherless, are fixed in one morphologically identical series, thus: 1, shoulder or hip-joint; 2, upper arm or thigh, humerus or femur; 3, elbow or knee-joint; 4, fore-arm or leg proper, radius and ulna or tibia and fibula; 5, wrist, bend of wing, carpus, or heel, ankle, tarsus; 6, hand proper, meta-

carpus, or foot proper, metatarsus; 7, digits with their phalanges, of hand or foot, fingers or toes. Observe the improper popular naming of these parts, in the case of the hind limb, whereby 1, 2, 3, are not generally counted; 4 is miscalled "thigh"; 5 is miscalled "knee"; 6 is miscalled "leg" or "shank"; 7 is miscalled "foot." Observe also that in descriptive ornithology 6 is "*the tarsus.*"

The Plumage of the Leg and Foot varies within wide limits. *In general*, the leg is feathered to the heel, *C*, and the rest of the limb is bare of feathers. The thigh is *always* feathered, as part of the body plumage (*pteryla femoralis*). The crus or leg proper (thigh of vulgar language, *B* to *C*) is feathered in nearly all the higher birds, and in swimming birds without exception; in the loons, the feathering even extends on the heel-joint. It is among the walking and especially the wading birds that the crus is most extensively denuded; it may be naked half-way up to the knee. A few waders —among British birds, chiefly in the snipe family—have the crus

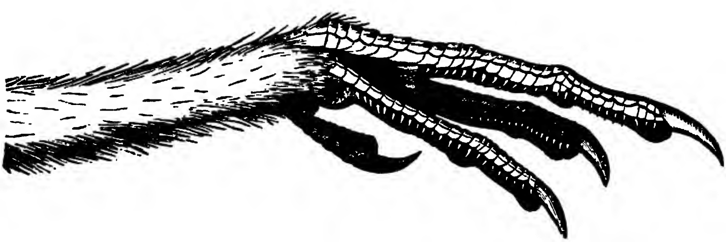


FIG. 35.—Feathered tarsus of the prairie-hen, *Cupidonia cupido*. Nat. size; from life by Coues.

apparently clothed to the heel-joint; but this is due, in most if not all cases, to the length of the feathers, for probably in none of them does the pteryla cruralis itself extend to the joint. Crural feathers are nearly always short and inconspicuous; but sometimes long and flowing, as in the "flags" of most hawks, and in the American tree-cuckoos (*Coccyzus*). The *tarsus* (I now and hereafter use the term in its ordinary acceptation—*C* to *D* in Fig. 34; *trs* in Fig. 36) in the vast majority of birds is entirely naked, being provided with a horny or leathery sheath of integument like that covering the bill. Such is its condition in the *Passeres* and *Picariæ* (with few exceptions, as among swifts and goatsuckers); in the waders without exception, and in nearly all swimmers (the frigate-bird, *Tachypetes*, has a slight feathering). The *Raptores* and *Gallinæ* furnish the most feathered tarsi. Thus, feathered tarsi is the rule among owls (*Striges*); frequent, either partial or complete, in hawks and eagles, as in *Aquila*, *Archibuteo*, *Falco*, *Buteo*, etc. All British grouse, and perhaps all true grouse, have the tarsus more or less feathered (Fig.

35). The *toes* themselves are feathered in a few birds, as several of the owls, and all the ptarmigans (*Lagopus*). Partial feathering of the tarsus is often continued downward, to the toes or upon them, by sparse modified feathers in the form of bristles; as is well shown in the barn-owl (Fig. 47). When incomplete, the feathering is generally wanting behind and below, and it is almost invariably continuous above with the crural plumage. But in that spirit of perversity in which birds delight to prove every rule we establish by furnishing exceptions, the tarsus is sometimes partly feathered discontinuously. A curious example of this is afforded by the bank-swallow, *Cotile riparia*, with its little tuft of feathers at the base of the hind toe; and some varieties of the barn-yard fowl sprout monstrous leggings of feathers from the side of the tarsus.

The Length of Leg, relatively to the size of the bird, is extremely variable; a thrush or sparrow probably represents about average proportions of the limb. The shortest-legged bird known is probably the frigate-pelican (*Tachypetes*); which, though a yard long, more or less, has a tibia not half as long as the skull, and a tarsus under an inch. The leg is very short in many Picarian birds, as hummers, swifts, goatsuckers, kingfishers, trogons, etc., in most of which it scarcely serves at all for progression. Among *Passeres*, the swallows resemble swifts in shortness of their hind limbs. It is pretty short likewise in many zygodactyl, yoke-toed, or scansorial birds, as woodpeckers, cuckoos, and parrots. In most swimming birds the limb may also be called short, especially in its femoral and tarsal segments; while the broad-webbed toes are comparatively longer. The leg lengthens in the lower perching birds, as many hawks and some of the terrestrial pigeons; it is still longer among walkers proper, such as the gallinaceous birds, and reaches its maximum among the waders, especially the larger ones, such as cranes, herons, ibises, storks, and flamingoes; among all of which it is correlated with extension of the neck. Probably the longest-legged of all birds for its size is the stilt (*Himantopus*). Taking the tarsus alone as an index of length of the whole limb, this is in the frigate under one-thirty-sixth of the bird's length; a flamingo, four feet long, has a tarsus a foot long; a stilt, fourteen inches long, one of four inches; so that the maximum and minimum lengths of tarsus are nearly thirty and under three per cent of a bird's whole length.

The Horny Integument of the Foot requires particular attention. That part of the limb which is devoid of feathers is covered, like the bill, by a hardened, thickened, modified integument, varying in texture from horny to leathery. This sheath is called the *podotheca* (Gr. πούς, ποδός, *pous*, *podos*, foot, and θήκη, *theke*, sheath). It is more corneous in land birds, and in water birds more leathery;

this general distinction has but few exceptions. The perfectly horny envelope is tight, and immovably fixed or nearly so, while the skinny styles of sheath are looser, and may usually be slipped about a little. The integument may differ on different parts of the same leg, and in fact generally does so to some extent. Unlike the sheath of the bill, the podotheca is never simple and continuous, being divided and subdivided in various ways. The lower part of the crus, when naked, and the tarsus and toes, always have their integument cut up into scales, plates, tubercles, and other special formations, which have received particular names. The manner and character of such divisions are often of the utmost consequence *in classification*, especially among the higher birds, since they are *quite significant of* genera, families, and even some larger groups.

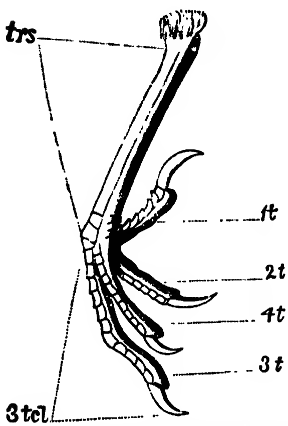


FIG. 36.—Booted laminiplantar tarsus of a robin (*Turdus migratorius*). Nat. size.

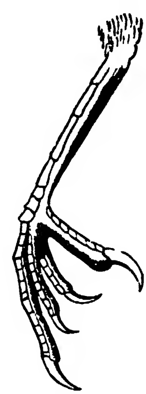


FIG. 37.—Scutellate laminiplantar tarsus of a cat-bird (*Mimus carolinensis*). Nat. size.

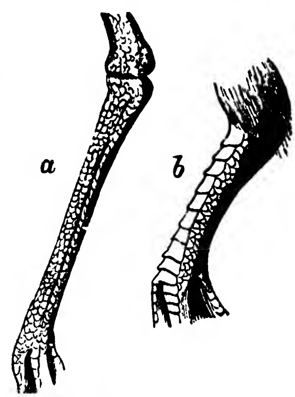


FIG. 38.—*a*, Reticulate tarsus of a plover. Nat. size. *b*, Scutellate and reticulate tarsus of a pigeon. Nat. size.

The commonest division of the podotheca is into *scales* or *scutella* (Lat. *scutellum*, a little shield; pl. *scutella*, not *scutellæ* as often written); Figs. 37 and 38, *b*. These are generally of large comparative size, arranged in definite vertical series up and down the tarsus and along the toes, and apt to be somewhat imbricated, or fixed shingle-wise, the lower edge of one overlapping the upper edge of the next. The great majority of birds have such scutella. They oftenest occur on the front of the tarsus (or *acrotarsium*, corresponding to our "instep"), and almost invariably on the tops of the toes (collectively called *acropodium*); frequently also on the sides and back (*planta*) of the tarsus; not so often on the crus; and rarely if ever on the sides and under surfaces of the toes. A tarsus so disposed as to its podotheca is said to be *scutellate*,—scutellate

before (Fig. 37), or behind, or both, as the case may be. The term is equally applicable to the acropodium, but is not so often used because scutellation of the upper sides of the toes is so universal as to be taken for granted unless the contrary condition is expressly said. The most notorious case of the *Oscine podotheca* (Figs. 36, 37), characterising that great group of birds, is given in the next paragraph.

Plates, or *reticulations* (Lat. *reticulum*, a web; Fig. 38, *a*) result from the cutting up of the envelope in various ways by cross lines. Plates are of various shapes and sizes, and grade usually into true scutella, from which, however, they are generally distinguished by being smaller, or of irregular contour, or not in definite rows, or lacking the appearance of imbrication; but there is no positive distinction. They are oftenest *hexagonal* (six-sided), a form best adapted to close packing, as shown very perfectly in the cells of the honey-bee's comb; but they may have fewer sides, or be *polygonal* (many-sided) or even circular; when crowded in one direction and loosened in another the shape tends to be oval or even linear. A leg so furnished is said to be *reticulate:* the reticulation may be entire, or be associated with scutellation, as often happens (Fig. 38, *b*). A particular case of reticulation is called *granulation* (Lat. *granum*, a grain), when the plates become elevated into little tubercles, roughened or not. Such a leg is said to be *granular*, *granulated* or *rugose:* it is well shown by parrots, and the osprey (*Pandion*). When the harder sorts of scales or plates are roughened without obvious elevation, the leg is said to be *scabrous* or *scarious* (Lat. *scabrum*, a scab). But *scabrous* is also said of the under surfaces of the toes, when these develop special *pads*, or wart-like bulbs (called *tylari*); as is well shown in many hawks. The softer sorts of legs, and especially the webs of swimming birds, are often marked crosswise or *cancellated* with a latticework of lines, these, however, not being strong enough to produce plates; it is more like the lines seen on our palms and finger-tips. The plates of a part of the leg occasionally develop into actual *serrations;* as witnessed along the hinder edge of a grebe's tarsus. When an unfeathered tarsus shows no divisions of the podotheca in front (along the acrotarsium), or only two or three scales close by the toes, it is said to be *booted* or *greaved;* and such a podotheca is *holothecal* (Gr. ὅλος, *holos*, whole, entire, and θήκη; Fig. 36). The generic opposite is *schizothecal* (Gr. σχίζω, I cleave), whether by scutellation, or reticulation, or in any other way the integument may be cut up. A booted or holothecal tarsus chiefly occurs in the higher *Oscines*, and is supposed by ornithologists to indicate the highest type of bird structure. It is, however, found in a few water birds, as Wilson's stormy petrel and other species of *Oceanites*. It is not a common modification.

Exceptions aside, it only occurs in connection with an equally particular condition of the *sides and back* of the tarsus, or *planta*. In almost all *Oscine Passeres* (*Alaudidæ* are an exception), which constitute the great bulk of the large order *Passeres*, the planta is covered with one pair of plates or *laminæ*, one on each side, meeting behind in a sharp ridge; a condition called *laminiplantar*, in distinction from the opposite, *scutelliplantar*, state of the parts. A holothecal podotheca only occurs in connection with the laminiplantar condition, the combination resulting in the perfect "boot." Among British birds it is exhibited by the following genera: *Turdus*, *Cinclus*, *Saxicola*, *Regulus*, *Cyanecula*, *Phylloscopus*; and even birds of these genera, when *young*, show scutella which disappear with age by progressive fusion of the acrotarsial podotheca. (Compare Figs. 36, 37.)

The Crus, when bare of feathers below, may, like the tarsus, be scutellate or reticulate before or behind, or both; such divisions of the crural integument being commonly seen in long-legged wading birds. Or, again, this integument may be loose, softish, and movable, not obviously divided, and passing directly into ordinary skin.

The Tarsus, in general, may be called subcylindrical: it is often quite circular in cross-section; generally thicker from before backward, and only rarely wider from one side to the other than in the opposite direction; but such a shape as this last is exhibited by the penguins. When the transverse thinness is noticeable, the tarsus is said to be *compressed*; and such compression is very great in a loon, in which the tarsus is almost like a knife-blade. Quite cylindrical tarsi occur chiefly when there are similar scales or plates before and behind, as happens in the larks (*Alaudidæ*); they are rare among land birds, common among waders. Those swimming birds which have a very thin skinny podotheca are apt to show traces of the four-sidedness of the metatarsal bone. The tarsus in the vast majority of land birds is seen on close inspection to be somewhat oval or drop-shaped on cross-section,—gently rounded in front, more compressed laterally, and sharp-ridged behind. This results from the *laminiplantation* described above, and is equally well exhibited by most passerine birds, whether they have booted or anteriorly scutellate tarsi. The line of union of anterior scutella with posterolateral plates on the sides of the tarsus is generally in a straight vertical line,—either a mere line of flush union, or a ridge, or oftener a groove (well seen in the crows), which may or may not be filled in with a few small narrow plates. In Clamatorial *Passeres* the tarsus is enveloped in a scroll-like podotheca of irregularly arranged plates, the edges of the scroll meeting along the inner side of the tarsus.—But the full consideration of special states of the

tarsal envelope, however important and interesting, would be part of a systematic treatise on ornithology, rather than of an outline sketch like this.

The Normal Number of Toes (individually, *digiti;* collectively, *podium*) is *four:* there are *never* more. There are two in the ostrich alone, in which both inner and hind toe are wanting. There are three in all the other struthious birds (*Rheidæ, Casuariidæ*), excepting *Apteryx*, which has four. There are likewise three, the hind toe being suppressed, in the tinamine genera *Calodromas* and *Tinamotis* (*Dromæognathæ*); throughout the auk family (*Alcidæ*); in the petrel genus *Pelecanoïdes;* apparently in the albatrosses (*Diomedeinæ ;* in these, however, there is a rudiment of the hind toe); usually in the gull genus *Rissa;* in the flamingo genus *Phœnicoparra;* throughout the bustard family (*Otididæ*), and among various related forms, as *Œdicnemus, Hæmatopus, Himantopus, Esacus, Cursorius;* in the plovers (*Charadriidæ*), excepting *Squatarola;* in the sandpiper genus *Calidris;* and in the bush-quails (*Turnicidæ*), excepting *Pedionomus.* In higher birds three toes are a rare anomaly, only known to occur in three genera of woodpeckers (*Picoïdes, Sasia,* and *Tiga*), and in one galbuline genus (*Jacamaralcyon*), by loss of the hind toe; in two genera of kingfishers (*Ceyx* and *Alcyone*), by suppression of the inner front toe; and in the passerine genus *Cholornis,* by defect of the outer front toe. Birds with two toes are said to be *didactyl;* with three, *tridactyl;* with four, *tetradactyl.* In the vast majority of cases birds have three toes in front and one behind. Occasionally either the hind toe or the outermost front toe is *versatile,* that is, susceptible of being turned either way. Such is the condition of the outer front toe in most owls (*Striges*), and in the osprey (*Pandion*). There is no case of true versatility of the hind toe among North American birds; but several cases of its stationary somewhat lateral position, as in goatsuckers (*Caprimulgidæ*), some of the swifts (*Cypselidæ*), the loons (*Colymbidæ*), and all the totipalmate swimmers (*Steganopodes*). The rarest of all conditions (seen in some *Cypselidæ*, and the African *Coliidæ*) is that in which all four toes are turned forward. The arrangement of toes in pairs, two before and two behind, is quite common, being characteristic of scansorial birds and some others, as all the parrots and woodpeckers, cuckoos, trogons, etc. Such arrangement is called *zygodactyl* or *zygodactylous* (Gr. ζυγόν, *zugon,* a yoke; δάκτυλος, *daktulos,* a digit); and birds exhibiting it are said

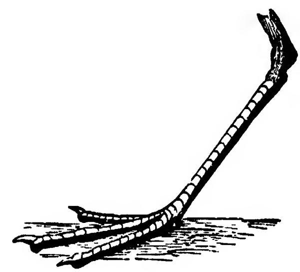


FIG. 39.—Tridactyle foot of sanderling, *Calidris arenaria;* nat. size.

to be *yoke-toed* (Fig. 45). In all yoke-toed birds, excepting the trogons, it is the outer anterior toe which is reversed; in trogons, the inner one; the latter are called *heterodactylous.* In nearly every three-toed bird, all three toes are anterior; an exception is in the genus *Picoïdes,* where the true hind toe is wanting, the outer anterior one being reversed as usual in zygodactyls. No bird has more toes behind than in front. Birds' toes, and their respective joints, are

Numbered, in a certain definite order, as follows (see Figs. 34, 36): hind toe = *first* toe, 1*t*; inner anterior toe = *second* toe, 2*t*; middle anterior toe = *third* toe, 3*t*; outer anterior toe = *fourth* toe, 4*t*. Such identification of 1*t*, 2*t*, 3*t*, 4*t* applies to the ordinary case of three toes in front and one behind. But, obviously, it holds good for any other arrangement of the toes, if we only know which one is changed in position,—a thing always easy to learn, as we shall see at once. In birds with the hind toe reversed, bringing all four in front, the same order is evident, though then 1*t* is the inner anterior, 2*t* the next, etc.; for it always happens, when a hind toe turns forward, that it turns on the *inner* side of the foot. Similarly, in yoke-toed birds (excepting *Trogonidæ*), it is the *outer* anterior which is turned backward, as above said; then, evidently, inner hind toe = 1*t*; inner front toe = 2*t*; outer front toe = 3*t*; outer hind toe = 4*t*. In *Trogonidæ,* with inner front toe reversed, the correction of the formula is easily made. Moreover, when the number of toes decreases from four to three or two, the digits are almost always reduced in the same order: thus, in three-toed birds, 1*t* is the missing one; in the two-toed ostrich, 1*t* and 2*t* are gone. Exceptions to this generalisation are afforded by two exotic genera of kingfishers, *Ceyx* and *Alcyone,* in which 2*t* is defective; and by the anomalous passerine *Cholornis* of China, in which 4*t* is in like case. The rule is proved by the

Number of Phalanges, or joints, of the digits. The constancy of the joints in birds' toes is remarkable,—it is one of the strongest expressions of the highly monomorphic character of *Aves.* In *all* birds, excepting *Procellariidæ,* 1*t* when present has *two* joints (not counting, of course, the accessory metatarsal). In *all* birds, 2*t* when present has *three* joints. In *nearly all* birds, 3*t* has *four* joints. In *nearly all* birds, 4*t* has *five* joints. Thus, any digit has one more joint than the number of itself. (See Fig. 34, where the digits and the phalanges are numbered.) The exceptions to this regularity consist in the lessening of the number of joints of 1*t* or 3*t* by *one,* and of 4*t* by *one* or *two.* So when the joints do not run 2, 3, 4, 5, for toes 1 to 4, they run either 1, 3, 4, 5, or 2, 3, 4, 4, or 2, 3, 3, 3. (These statements do not regard the anomalous cases of *Ceyx, Alcyone,* and *Cholornis*—see above.) This variability is nearly confined to certain Picarian birds: examples

of it are in certain genera of *Cypselinæ*, Fig. 40, where the ratio is 2, 3, 3, 3, of *Caprimulginæ*, Fig. 41, where it is 2, 3, 4, 4; and the petrel family, with 1, 3, 4, 5. Such admirable conservatism enables us to tell what toes are missing in any case, or what ones are out of the regular position. Thus, in *Picoïdes*, the hind toe, apparently 1*t*, is known to be 4*t*, because it is five-jointed; in a trogon, the inner hind toe is 2*t*, being three-jointed; in the ostrich, with only two toes, 3*t* and 4*t* are seen to be preserved, because they are respectively four- and five-jointed. Besides this interesting numerical ratio, the phalanges have other inter-relations of some consequence in classification, resulting from their comparative lengths. In some families of birds, one or more of the *basal* or proximal phalanges (those next to the foot—opposed to *distal*, or those at the ends of the digits) of the front toes are extremely short, being mere nodules of bone (Fig. 40); in other and more frequent cases, they are the longest of all, as in Figs. 34, 41. On the whole, they generally decrease in length from proximal to distal extremity, and the last one of any toe is quite small, serving merely as a core to the claw. The difference in the lengths of the several phalanges, like that of the digits themselves, makes the toes more efficient in grasping, since they thereby clasp more perfectly upon an irregular object. The design and the principle are the same as seen in the human hand, in which model instrument the digits and their respective joints are all of different lengths.

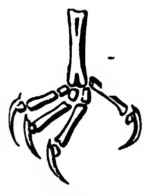


FIG. 40.—Phalanges of Cypseline foot, 2, 3, 3, 3. After Sclater.

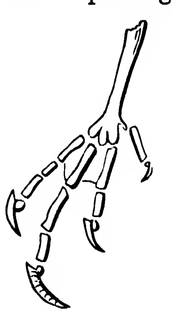


FIG. 41.—Phalanges of Caprimulgine foot, 2, 3, 4, 4. After Sclater.

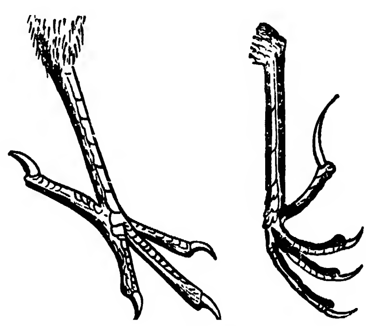
The Position of the Digits, other than in respect to their *direction*, is important. In all the birds front toes are inserted on the metatarsus on the same level, or so nearly in one horizontal plane that the difference is not notable. The same may be said of the hind toes when they are a pair, as in zygodactyle birds. But the hind toe, or *hallux*, as it is called, when present and single, varies remarkably in position with reference to the front toes; and this matter requires special notice, as it is important in classification. The insertion of this digit varies from the very bottom of the tarsus (*metatarsus*), where it is on a level with the front toes, to some distance up that bone. When the hallux is flush with the bases of the other toes, so that its whole length is on the ground, it is said to be *incumbent*. When just so much raised that its tip only touches the ground, it is called *insistent*. When inserted so high up that it does not reach the ground, it is termed *remote* (*amotus*) or *elevated*. But as the precise

position varies insensibly, so that the foregoing distinctions are not readily perceived, it is practically best to recognise only two of these three conditions, saying simply "hind toe elevated," when it is inserted fairly above the rest, and "hind toe not elevated," when its insertion is flush with that of the other toes. In round terms: it is characteristic of all *insessorial* (Lat. *insedo*, I sit upon) or perching birds to have the hind toe DOWN; of all other birds to have it UP (when present). The exceptions to the first of these statements are extremely rare.

The Hallux has other Notable Characters.—It is *free* and *simple*, in the vast majority of birds: in all *insessorial* birds, nearly all *cursorial* (Lat. *cursor*, a courser), and most *natatorial* (Lat. *natator*, a swimmer) forms. Its length, claw included, may equal or surpass that of the longest anterior toe; and generally exceeds that of one or two of these. It is always longest when *incumbent;* when thus down on a level with the rest it also acquires its greatest mobility and functional efficiency. In most *Passeres* it has a special muscle for independent movement, so that it may be perfectly apposable to the other toes collectively, just as our thumb may be brought against the tip of any finger. In general, it shortens as it rises on the metatarsus; and probably in no bird in which it is truly elevated is it as long as the shortest anterior toe. It is short, barely touching the ground, in most wading birds; shorter still in some swimmers, as the gulls, where it is probably functionless; it is incomplete in one genus of gulls (*Rissa*), where it bears no perfect claw; it has only one phalanx and is represented only by a short immovable claw in the petrels (*Procellariidæ*); it disappears in the birds named in the last paragraph but two above, and in some others. It is never actually soldered with any other toe for any noticeable distance; but it is webbed to the base of the inner toe in the loons (*Colymbus*), and to the whole length of that toe in all the *Steganopodes* (Fig. 52). It may also be independently webbed; that is, be provided with a separate flap or lobe of free membrane. This lobation of the hallux is seen in all our sea-ducks and mergansers (*Fuligulinæ* and *Merginæ*), and in all the truly lobe-footed birds, as coots (*Fulica*), grebes (*Podicipedidæ*), and phalaropes (*Phalaropodidæ*). The modes of union of the anterior toes with one another may be finally considered under the head of the

Three leading Modifications of the Avian Foot.—Birds' feet are modelled, on the whole, upon one or another of three plans, furnishing as many *types of structure;* which types, though they run into one another, and each is variously modified, may readily be appreciated. These plans are the perching or *insessorial;* the walking or wading, *cursorial* or *grallatorial;* and the swimming or

natatorial—in fact, so well distinguished are they, that carinate birds have even been primarily divided into groups corresponding to these three evidences of physiological adaptation of the structure of the Avian *pes*. Independently of the number and position of the digits, the plans are pretty well indicated by the method of union of the toes, or their entire lack of union. 1. *The insessorial type.* (*a*) In order to make a foot the most of *a hand*, that is, to fit it best for that grasping function which the perching of birds upon trees and bushes requires, it is requisite that the digits should be as free and movable as possible, and that the hind one should be perfectly apposable to the others. Compare the human hand, for example, with the foot, and observe the perfection secured by the entire freedom of the fingers, and especially the appositeness of the thumb. In the most accomplished insessorial foot, the front toes are *cleft to the base*, or only coherent to a very slight extent; the hind toe is completely incumbent, and as long and flexible as the rest. The thrushes (*Turdidæ*) probably show as complete cleavage as is ever seen, practically as much as that of the human fingers; the cleft between the inner and middle toe being to the very base, while the outer is only joined to the middle for about the length of its own basal joint. This is the typical *passerine* foot (Figs. 36, 37, 42, 43). There may be somewhat more cohesion of the toes at base, as in the wrens, titmice, creepers, etc., without, however, obscuring the true passerine character.



FIGS. 42, 43.—Typical passerine feet. (The right-hand fig. is *Plectrophanes lapponicus*, nat. size.)

Besides the typical passerine, there are several other modifications of the insessorial foot. (*b*) Thus a kingfisher shows what is called a *syndactyl* or *syngnesious* (Gr. σύν, *sun*, together; γνήσιος, *gnesios*, relating to way of birth; Fig. 44) foot where the outer and middle toes cohere for most of their extent and have a broad sole in common. It is a degradation of the insessorial foot, and not a common one either; seen in those perching birds which scarcely use their feet for progression, but simply for sitting motionless. (*c*) The *zygodactyl* or yoke-toed modification has been sufficiently noted (Fig. 45). It was formerly made much of, as a *scansorial* or *climbing* type of foot, and an absurd "order" of birds has been called *Scansores*. But many of the zygodactyl birds do not climb, as the cnckoos; while the most nimble and adroit of climbers, such as nuthatches and creepers, retain a typically passerine foot. The

"scansorial" is simply one modification of the insessorial plan, and has little classificatory significance—no more than that attaching to the particular condition of the insessorial foot (*d*) which results from elevation or versatility of the hind toe, as in some *Cypselidæ* and *Caprimulgidæ*. This is an abnormality which has received no

FIG. 44. — Syndactyle foot of kingfisher, nat. size.

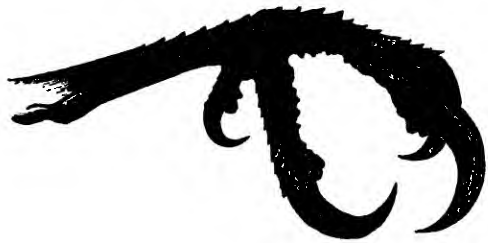


FIG. 45.—Zygodactyle foot of a woodpecker, *Hylotomus pileatus*, nat. size. From nature by Coues.

special name; it is generally associated with some little webbing of the anterior toes at base, which is a departure from the true insessorial plan, or with abnormal reduction of the phalanges of the third and fourth toes, as explained above (Figs. 40, 41). (*e*) The *raptorial* is another modification of the insessorial foot. It is

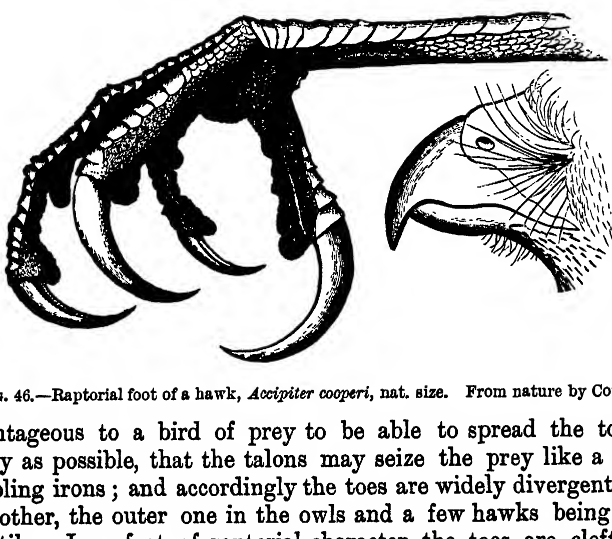


FIG. 46.—Raptorial foot of a hawk, *Accipiter cooperi*, nat. size. From nature by Coues.

advantageous to a bird of prey to be able to spread the toes as widely as possible, that the talons may seize the prey like a set of grappling irons; and accordingly the toes are widely divergent from each other, the outer one in the owls and a few hawks being quite versatile. In a foot of raptorial character, the toes are cleft pro-

foundly, or, if united at base, it is by movable webbing; the claws are immensely developed, and the under surfaces of the toes are scabrous or bulbous for greater security of the object grasped. Any hawk or owl or old-world vulture exhibits the raptorial or insessorial foot (Figs. 46, 47). 2. *The cursorial* or *grallatorial type.* The gist of this plan lies in the decrease or entire loss of the grasping function, and in the elevation, reduction in length, or loss of the hind toe; the foot is a good foot, but nothing of a hand. The columbine birds, which are partly terrestrial, partly arboreal, exhibit the transition from the perching to the gradient foot, in some reduction of the hind toe, which is nevertheless in most cases still on the same level as the rest (Fig. 38, *b*). In the gallinaceous or rasorial (Lat. *rasor*, a scraper) birds, which are essentially terrestrial, and noted for their habit of scratching the ground for food, the

FIG. 47.—Raptorial foot of an owl, *Aluco flammeus*, nat. size. From nature by Coues.

hind toe is decidedly elevated and shortened in almost all of the families (Fig. 35). Such reduction and uplifting of the hallux is carried to an extreme in most of the waders, or *Grallatores*, in many of which this toe disappears (Figs. 38 *a*, 39). It is scarcely practicable to recognise special modifications of such gradient or grallatorial feet, since they merge insensibly into one another. The herons, which are the most arboricole of the waders, exhibit a reversion to the insessorial type, in the length and incumbency of the hallux. The mode of union of the front toes of the walkers and waders is somewhat characteristic. The toes are either cleft quite to the base, or there joined by small webs; probably never actually coherent. Such basal webbing of the toes is called *semipalmation* ("half-webbing"). It is actually the same thing that occurs in many birds of prey, in most gallinaceous birds, etc.; the term is mostly restricted, in descriptive ornithology, to those *wading* birds, or *Grallatores*, in which it occurs. Such basal webs generally run out

to the end of the first, or along part of the second, phalanx of the toes; usually farther between the outer and middle than between the middle and inner toes. Such a foot is well illustrated by the semipalmated plover *Ægialites semipalmatus*), semipalmated sandpiper (*Ereunetes pusillus*, Fig. 48), and willet (*Symphemia semipalmata*, Fig. 49). In a few wading birds, as the avocet and flamingo, the webs extend to the ends of the toes. This introduces us at once to the *third* main modification of the foot. 3. *The natatorial type.* Here the foot is transformed into a swimming implement, usually with much if not entire abrogation of its function as a hand. Swimming birds, with few exceptions, are bad walkers, and few of them are perchers. The swimming type is presented under two principal modifications:—(*a.*) In the *palmate* or ordinary webbed foot, all the front toes are united by ample webs (Fig. 50). The palmation

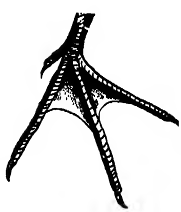


FIG. 48.—Semipalmation in *Ereunetes*; nat. size.

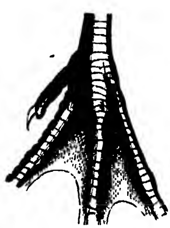


FIG. 49.—Semipalmated bases of toes of *Symphemia*; nat. size.

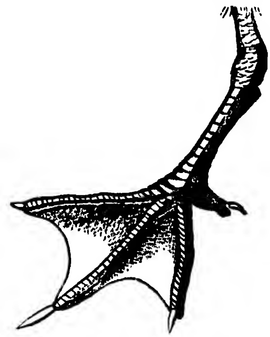


FIG. 50.—Palmate foot of a tern, *Sterna forsteri*; nat. size.

is usually complete, extending to the ends of the toes; but one or both webs may be so deeply *incised*, that is, cut away, that the palmation is practically reduced to semipalmation, as in terns of the genus *Hydrochelidon* (Fig. 51). The *totipalmate* is a special case of palmation, in which all four toes are webbed; this characterises the whole order *Steganopodes* (Fig. 52). (*b.*) In the *lobate* foot, a paddle results not from connecting webs, but from a series of *lobes* or flaps along the sides of the individual toes; as in the coots, grebes, phalaropes, and sun-birds (*Heliornithidæ*.) Lobation is usually associated with semipalmation, as is well seen in the grebes (*Podicipedidæ*). In the phalaropes (*Phalaropodidæ*, Fig. 53 *bis*) lobation is present as a modification of a foot otherwise quite cursorial. The most emphatic cases of lobation are those in which each joint of the toes has its own flap, with a free convex border; the membranes as a whole therefore present a scolloped outline (Figs. 53, 53 *bis*). Such lobes are merely a development of certain *margin*

fringes or processes exhibited by many non-lobate or non-palmate birds. Thus, if the foot of some of the gallinules be examined in a fresh state, the toes will be seen to have a narrow membranous margin running the whole length. The same thing is evident in

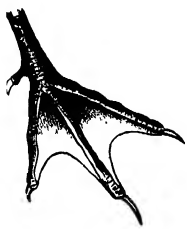


FIG. 51.—Incised palmation of *Hydrochelidon lariformis*; nat. size.

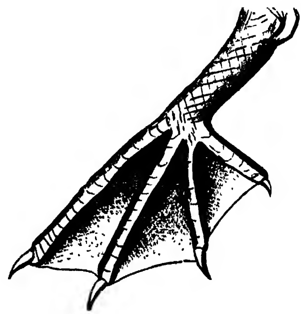


FIG. 52.—Totipalmate foot of a pelican; reduced.

a great many waders, and on the free borders of the inner and outer toes of web-footed birds. In the grouse family (*Tetraonidæ*) marginal fringes are very conspicuous; there being a great development of hard horny substance, fringed into a series of sharp teeth or *pectinations* (Fig. 35). These formations appear to be deciduous,

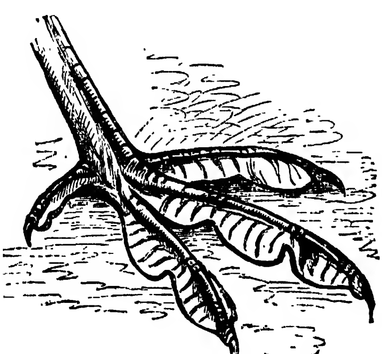


FIG. 53.—Lobate foot of a coot; reduced.

FIG. 53 *bis*.—Lobate foot of phalarope, *Lobipes hyperboreus*; nat. size.

that is, to fall off periodically, like parts of the claws of some quadrupeds (lemmings).

Claws and Spurs.—With rare anomalous exceptions, as in the case of an imperfect hind toe, every digit terminates in a complete *claw*. The general shape is remarkably constant in the class;

variations being rather in degree than in kind. A cat's claw is about the usual shape: it is *compressed, arched, acute*. The great talons of a bird of prey are only an enlargement of the typical shape; and, in fact, they are scarcely longer, more curved, or more acute, than those of a delicate canary bird; they are simply stouter. The claws of scansorial birds are very acute and much curved, as well as quite large. The under surface of the claw is generally excavated, so that the transverse section, as well as the lengthwise outline below, is concave, and the under surface is bounded on either side by a sharp edge. One of these edges, particularly the inner edge of the middle claw, is expanded or dilated in a great many birds; in some it becomes a perfect *comb*, having a regular series of teeth. This *pectination* (Lat. *pecten*, a comb), as it is called, only occurs on the inner edge of the middle claw. It is beautifully shown by all the true herons (*Ardeidæ*); by the goatsuckers

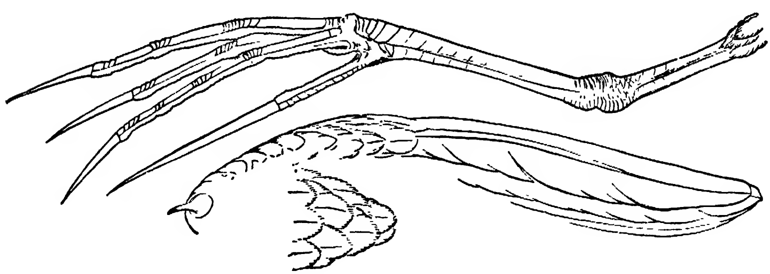


FIG. 53 *ter*.—Foot of *Parra gymnostoma*, nat. size, showing the long, straight claws. (From Ridgway Mus. The *spurred* wing of the same bird is also shown. See p. 168.)

(*Caprimulgidæ*, Fig. 41); by the frigate pelican (*Tachypetes*); and imperfectly by the barn-owl (*Aluco flammeus*). It is supposed to be used for freeing parts of the plumage that cannot be reached by the bill from parasites; but this is very questionable, seeing that some of the shortest-legged birds, which cannot possibly reach much of the plumage with the comb, possess that instrument. Claws are more *obtuse* among the lower birds than in the insessorial and scansorial groups, as the columbine and gallinaceous (*rasorial*) orders, and most natatorial families. Obtuseness is generally associated with flatness or depression; for in proportion as a claw becomes less acute, so does it lose its arcuation, as a rule. This is well illustrated by Wilson's petrel (*Oceanites oceanicus*), as compared with others of the same family. Such condition is carried to an extreme in the grebes (*Podicipedidæ*), the claws of which birds resemble human finger-nails. Otherwise, deviations from curvature, without loss of acuteness, are chiefly exhibited by the hind claw of many

terrestrial *Passeres*, as in the whole family *Alaudidæ* (larks), and some of the finches (*Fringillidæ*), as the species of "long-spur" (*Centrophanes*). But all the claws are straight, sharp, and prodigiously long, in birds of the genus *Parra* (Fig. 53 *ter*); these jaçanás being enabled to run lightly over the floating leaves of aquatic plants by such increase in the spread of their toes. Claws are also variously *carinate* or ridged, *sulcate* or grooved. In a few cases they are rounded underneath, so as to be nearly circular in cross-section, as is the case with those of the osprey (*Pandion*). They are always horny (*corneous*). They take name from, and are reckoned by, their respective digits: thus, 1 *cl.* = claw of 1*t*; 2 *cl.* = claw of 2*t*, etc.

Spurs (Lat. *calcar*, a spur) are developed on the metatarsal bones of a few birds. They are of the nature of claws, being hard, horny modifications of the epiderm: but they have nothing to do with the digits. They possess a bony core upon which they are supported, like the horns of cattle. Such growths chiefly occur in gallinaceous birds: the spurs of the domestic fowl are a familiar case. Sometimes there are a pair of such weapons on each foot, as in the *Pavo bicalcaratus*, and there may be several more, as in the genus *Ithagenis*. Another instance of their occurrence is offered by the wild turkey (*Meleagris gallipavo*). Metatarsal spurs are characteristic of the male sex; they are offensive weapons, and belong to the class of "secondary sexual characters" (p. 133). (For wing-spurs, as shown in Fig. 53 *ter*, see p. 168.)

§ 4.—AN INTRODUCTION TO THE ANATOMY OF BIRDS

Anatomical Structure now affords ornithologists many and the most important of the characters used in classification. In fact, few if any of the groups above genera can be securely established without consideration of internal parts and organs, as well as of exterior modifications of structure. Therefore, the student who really "means business" must be on speaking terms at least with avian anatomy. For example, none could in the least intelligently understand a wing or a leg without knowing the bony framework of those members. Yet to adequately set this matter forth would be to occupy a very much larger volume with anatomy; whereas, I can only devote a few pages to the entire subject. In such embarrassment, which attends any attempt to treat a great theme in a short way that shall not also be a small way, attention must be mainly confined to those points which bear most directly upon systematic ornithology as distinguished from pure anatomy, in order to bring

in the lungs; such sacs, sometimes of great extent, are also found in many places in the interior of the body, beneath the skin, etc.; sometimes the whole subcutaneous tissue is pneumatic. The extent to which the skeleton is aerated is very variable. In many birds only the skull, in a few the entire skeleton, is in such condition; ordinarily the greater part of the skull, and the lesser part of the trunk and limbs, is pneumatised. The passage of air in some cases is so free, as into the arm-bone, for example, that a bird with the windpipe stopped can breathe for an indefinite period through a

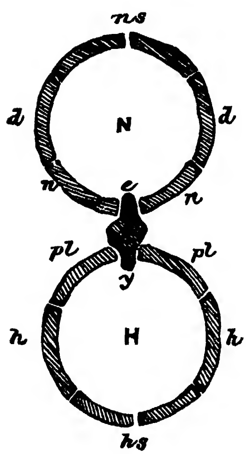


FIG. 54.—Ideal plan of the double-ringed body of a vertebrate. *N*, neural canal; *H*, hæmal canal; the body separating them is the centrum of any vertebra, bearing *e*, an epapophysis, and *y*, a hypapophysis; *n*, *n*, neurapophyses; *d*, *d*, diapophyses; *ns*, bifid neural spine; *pl*, *pl*, pleurapophyses; *h h*, hæmapophyses; *hs*, bifid hæmal spine. Drawn by Dr. R. W. Shufeldt, U.S.A., after Owen.

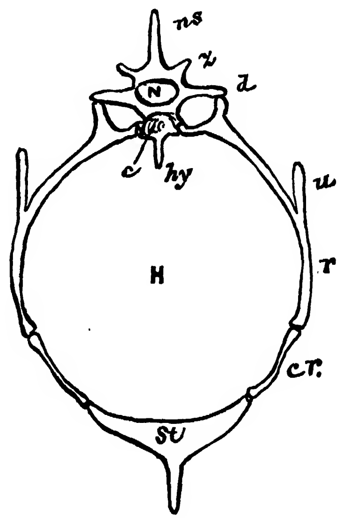


FIG. 55.—Actual section of the body in the thoracic region of a bird. *N*, neural canal; *H*, hæmal canal; *c*, centrum of a dorsal vertebra; *hy*, hypapophysis; *d*, diapophysis; *z*, zygapophysis; *ns*, neural spine; *r*, pleurapophysis, or vertebral part of a free rib, bearing *v*, uncinate process or epipleura; *cr*, hæmapophysis or sternal part of the same; *st*, section of sternum or breast-bone (hæmal spine). Designed by Dr. R. W. Shufeldt, U.S.A.

hole in the humerus. Pneumaticity is not directly nor necessarily related to power of flight; some birds which do not fly at all are more pneumatic than some of the most buoyant. (On the general pneumaticity of the body see beyond, under head of the Respiratory System.)

The Axial Skeleton (Figs. 54, 55, 56) of a bird or any *vertebrated* animal, that is, one having a back-bone, exhibits in cross-section two rings or hoops, one above and the other below a central point, like the upper and lower loops of a figure 8. The upper ring is the *neural arch* (Gr. *νεῦρον*, *neuron*, a nerve), so called because such a

cylinder encloses a section of the cerebro-spinal axis, or principal nervous system of a vertebrate (brain and spinal cord, whence arise

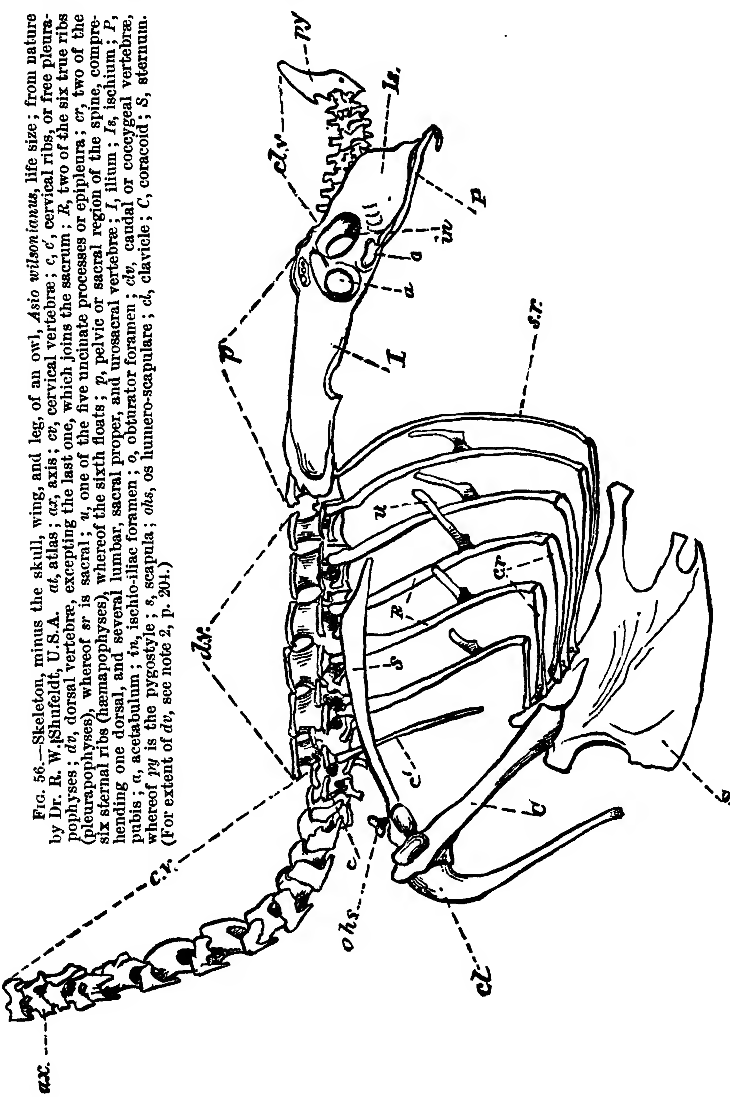


FIG. 56.—Skeleton, minus the skull, wing, and leg, of an owl, *Asio wilsonianus*, life size; from nature by Dr. R. W. Shufeldt, U.S.A. *at*, atlas; *ax*, axis; *cv*, cervical vertebræ; *c*, *c'*, cervical ribs, or free pleurapophyses; *dv*, dorsal vertebræ, excepting the last one, which joins the sacrum; *R*, two of the six true ribs (pleurapophyses), whereof *sr* is sacral; *u*, one of the five uncinate processes or epipleura; *cr*, two of the six sternal ribs (hæmapophyses), whereof the sixth floats; *p*, pelvic or sacral region of the spine, comprehending one dorsal, and several lumbar, sacral proper, and urosacral vertebræ; *I*, ilium; *Is*, ischium; *P*, pubis; *a*, acetabulum; *in*, ischio-iliac foramen; *o*, obturator foramen; *clv*, caudal or coccygeal vertebræ, whereof *py* is the pygostyle; *s*, scapula; *ohs*, os humero-scapulare; *cl*, clavicle; *C*, coracoid; *S*, sternum. (For extent of *dv*, see note 2, p. 204.)

all the nerves of the body, excepting those of the sympathetic nervous system). The lower ring is the *hæmal arch* (Gr. αἷμα, *haima*,

blood), which similarly contains a section of the principal blood-vessels and viscera. Fig. 55 shows such a section, made across the *thoracic* or chest region of the trunk. Here the upper ring (neural) is contracted, only surrounding the slender spinal cord, while the lower ring is expanded to enclose the heart and lungs. Such a section, made in the region of the skull, would show the reverse; the upper ring greatly inflated to contain the brain, the lower contracted and otherwise greatly modified into bones of the jaws. Thus the trunk of a vertebrate is a double-barrelled tube; one tube above for the axial nervous system, the other below for the viscera at large; the partition between the two being a jointed chain of solid bones from one end of the body to the other. These solid bones are the *centrums* or *bodies of vertebræ*, in the trunk; and in the head certain bones which in some respects correspond with the centrums of vertebræ. The entire chain or series of vertebræ composes the back-bone or *spinal column;* with its connections (thorax) and anterior continuation (skull) it is the *axial skeleton.* The skull is considered by some competent anatomists to consist of modified vertebræ. The skull-bones have certainly the position and relations of parts of vertebræ; to a certain extent they resemble vertebræ, as in being divisible into several segments, like as many vertebral segments; they are also directly in the axis of the body, enclosing a part of the cerebro-spinal nervous system above, and portions of the visceral systems below. But supposed strict morphological correspondence of cranial bones with vertebræ is not supported by their mode of development, and is now generally denied, the relation being considered rather analogical and physiological than homological and morphological.

1. THE SPINAL COLUMN

A Vertebra (so called from the flexibility of the chain of vertebræ; Lat. *verto*, I turn) consists of a solid body or *centrum*, and more or fewer processes or *apophyses*, some of which have separate ossific centres. Plate-like processes which arch upward from either side of a centrum to enclose the neural canal are the *neural arches* or *neurapophyses* (Fig. 54, *n*, *n*); at their union in the middle line above they commonly send up a process called the *neural spine* (*ns*). Transverse processes from the sides of the neural arch are *diapophyses* (Gr. διά, *dia*, across; Figs. 54, 55, *d*, *d*). Oblique processes from the sides of the same arches, serving to lock them together, are *zygapophyses* (Gr. ζυγὸν, *zugon*, a yoke; Fig. 55, *z*); there are two on each side; one anterior, on the front border of an arch, a *prezygapophysis;* one posterior, on the hind border, a *postzygapophysis.* From the under side of a centrum, in the middle

line, there is often a *hypapophysis* (Gr. ὑπό, *hupo*, under; Fig. 55, *hy*). These several processes, with some others not necessary to mention here, make with the centrum *a vertebra* in strictness; that is, when existing at all, they are completely consolidated with one another and with the centrum into one bone. But certain important elements of a vertebra, developed from independent ossific centres, may or may not ankylose therewith, in different regions of the same spinal column. These are the *pleurapophyses* (Gr. πλευρόν, *pleuron*, a rib; Fig. 54, *pl*; Fig. 55, *r*). Any *rib* is in fact the pleurapophysial element of a vertebra; it may be, and in most regions of the spinal column it is, quite small when existing at all, and ankylosed with the vertebra to which it belongs, as an integral portion thereof. But in the lower region of the neck, and throughout the thoracic region, such pleurapophyses elongate, and are movably articulated with their respective vertebræ; they then become the "ribs" of ordinary language. Moreover, the true thoracic ribs of birds are jointed near the middle, each thus consisting of two pieces; the upper piece is pleurapophysis proper: the lower is called a *hæmapophysis* (Fig. 54, *h*; Fig. 55, *cr*); it corresponds to a "costal cartilage" of human anatomy. Once again: since the *sternum* (breast-bone) is theoretically, and doubtless archetypically, a solidified set of those parts of the vertebral segments which complete the hæmal arches below, each segment of a sternum to which a hæmapophysis is articulated is called a *hæmal spine*, being compared to a neural spine above. Aside from any consideration of the ribs proper and sternum, or free pleurapophyses, hæmapophyses, and hæmal spines, any "vertebra" of ordinary language is the compound bone which consists of centrum and neur-, di-, pre-, and post-zyg-, pleur-, hyp-, and other -apophyses, if any, and neural spine; the latter often called "spinous process."

The Vertebræ join one another, forming a continuous chain. Their centra are placed end to end, one after another; their neural arches are also locked together by the zygapophyses, when these articular processes are developed. Zygapophyses bear upon their free ends smooth articular facets, the faces of which are mostly horizontal; those of the prezygapophyses looking downward, and overriding the reversed faces of the postzygapophyses. The mode of jointing of the centra of such vertebræ as are freely movable upon each other is highly characteristic of birds, in so far as the shapes of the articular ends of the vertebral centra are concerned. In anatomy at large, a vertebral centrum which is cupped or hollowed at both ends is of course biconcave. Such a vertebra is called *amphicœlous* (Gr. ἀμφί, *amphi*, on both sides; κοῖλος, *koilos*, hollowed); this is the rule in fishes, and obtained in some extinct Cretaceous birds, as

Ichthyornis; it is unknown in recent birds.[1] A centrum cupped in front only is *procœlous;* one cupped only behind is *opisthocœlous* (Gr. ὄπισθε, *opisthe*, behind). Such structure results in a ball-and-socket jointing of vertebræ. In those vertebræ of birds in which this arrangement obtains, it is always the *posterior* face of a centrum which is cupped, the anterior one being balled; such vertebræ are therefore opisthocœlous. But in the freest vertebral articulation of birds, that existing in the region of the neck, another modification occurs. Both ends of each vertebra are *saddle-shaped, i.e.* concave in one direction, convex in the other; a condition which is called *heterocœlous* (Gr. ἕτερος, *heteros*, contrary). The concavo-convexity of any one vertebra fits the reciprocal concavo-convexity of the next. *Anterior* faces of heterocœlous vertebræ are concave crosswise, up-and-down convex; *posterior* faces are the reverse; consequently, such vertebræ are procœlous in horizontal section, but in vertical section opisthocœlous. The various physical characters of vertebræ in different regions of the body, and their connections with and relations to other parts of the body, have caused their division into several sets, as cervical, dorsal, etc., which are best considered separately.

Cervical Vertebræ (Fig. 56, *cv*) are those of the *neck:* all those in front of the thorax or chest, which do not bear free pleurapophyses in adult life, or the free pleurapophyses of which, if any, are not in two-jointed pieces and do not reach the breast-bone; *i.e.* have no hæmapophyses. It is advisable, in birds, to draw this line between cervical and succeeding vertebræ, no other being equally practicable; for, on the one hand, one, two, or more of the cervicals (recognisable as such by their general conformation and free articulation) may have long free ribs, movably articulated; and all the cervicals, excepting usually the first, or first and second, have short pleurapophyses, ankylosed in adult life, but free in the embryo; while, on the other hand, a vertebra, apparently dorsal by its configuration and even its ankylosis with the dorsal series, may be entirely cervical in its pleurapophysial character.[2] Thus, in Fig. 56, of an owl's trunk, the bone which is apparently first dorsal, and is so marked (*dv*), bears a free styliform "riblet" an inch long (*c'*), only

[1] Except to this statement, however, the oddly-massed pygostyle, which, in birds where a terminal disk develops inferiorly, may be distinctly cupped at both ends, as it is in a raven, for example.

[2] The case is very puzzling; the more so because, viewing the whole series of birds, the ambiguous "cervico-dorsal," or two such equivocal vertebræ, may lean in different cases in opposite directions when the whole sum of characters is taken into account. Therefore it may be best, as already said, to make the possession of a jointed sternum-reaching rib the criterion of the *first* dorsal vertebra, even though an antecedent one may have the physical characters of a dorsal, and be ankylosed with the dorsal series. This is the view taken by Huxley, who says: "The first dorsal vertebra is defined as such by the union of its ribs with the sternum by means of a

it is not jointed, and does not reach the sternum; while the next to the last cervical has a minute but still free rib (*c*). In a raven's neck before me, the last cervical rib is about two inches long, articulating by well-defined head and shoulder to body and lateral process of the vertebra; the penultimate rib is about half an inch long, with one articulation to the lateral process; while the next anterior vertebra (third from the last) has a minute ossicle, as a free "riblet." The rule is *two* such free pleurapophyses or cervical ribs of any considerable length: sometimes one; rarely, three; in the cassowary four. Rudimentary pleurapophyses may usually be traced up to the second cervical vertebra, as slender stylets or riblets, completely ankylosed with the neural arches in adult life, and lying parallel with the long axes of the bones. The ankylosis of pleuropophyses distinguishes most cervical vertebræ in another way: for from it results, on each side of the neural arch, a *foràmen* (Lat. *foramen*, a hole, pl. *foramina*), through which blood-vessels (vertebral artery and vein) pass to and from the skull. The series of these foramina is called the *vertebrarterial canal;* none such exist in those posterior cervical vertebræ which bear free ribs; thus, in the raven the canal begins abruptly at the *fourth* from the last cervical. But, as in *Rhea*, for instance (and doubtless in many other cases), the vertebrarterial canal shades visibly into the series of foramina formed by the spaces between the head and shoulder of any rib and the side of the vertebra to which it is attached; such being the true morphology of the canal. The cervical is the most *flexible* region of a bird's spine; the articular ends of the vertebral bodies are the most completely saddle-shaped (heterocœlous); the zygapophyses are large and flaring, overriding each other extensively; the largest processes are at the fore ends of the bones; the appositions of the central and zygapophysial articular surfaces are collectively such, that the column tends to bend in an S-shape or sigmoid curve. The vertebral bodies are more or less contracted in the middle, or somewhat hourglass-shaped; on several lower cervicals hypapophyses are likely to be well developed; as are neural spines toward both the beginning and end of the series. The vertebræ on the whole are large; their neural canal is also of ample calibre. The first two cervicals are so peculiarly modified for the articulation of the skull as to have received special names.

sternal rib." (*Anat. Vert. Anim.*, 1872, p. 237.) Owen appears to regard as dorsal any of the vertebræ in question which bear free ribs. The actual uncertainty in the case, and the discrepant reckoning by different authors, prevents us from making a satisfactory count of the numbers of the two series of vertebræ in any given case. Thus, Fig. 56, as marked by Dr. Shufeldt, shows *six* dorsals (*dv*), to which is to be added the one under *p*, bearing the rib *sr*; and from which is to be subtracted the anterior one, bearing the rib *c'*, which is to be regarded as cervical, though its physical characters are evidently those of the dorsal series.

The *first* one, Fig. 56, *at*, the *atlas* (so called because it bears up the head, as the giant Atlas was fabled to support the firmament), is a simple ring, apparently without a centrum. The lower part of the ring is deeply cupped to receive the condyle of the occiput into a ball-and-socket joint. The *second* cervical is the *axis*, *ax*, which subserves rotary movements of the skull. It has a peculiar tooth-like *odontoid* (Gr. ὀδούς, ὀδόντος, *odous*, *odontos*, tooth; εἶδος, *eidos*, form) process, borne upon the anterior end of its body, fitting into the lower part of the atlantal ring; about which pivot the atlas, bearing the head, revolves like a wheel upon an eccentric axis. The cervicals of birds vary greatly in number; according to Huxley there are never fewer than eight, and there may be as many as twenty-three; Stejneger gives twenty-four for some of the swans. Twelve to fourteen may be about an average number.

Thoracic or Dorsal Vertebræ (Fig. 56, *dv*) extend from the cervical to or into the pelvic region of the spine. In most animals, and in ordinary anatomical language, a "dorsal" is one which bears a distinct free rib, and is therefore truly thoracic, since "ribs" are the side-walls of the chest. But in birds, as we have seen, certain cervicals have distinct elongate ribs; and, as will be seen soon, long jointed pleurapophyses are usually found in that region commonly called "sacral." The first dorsal, in birds, is arbitrarily considered to be that one which bears the first rib which is jointed, and which reaches the sternum by its lower (hæmapophysial) half. Five or six vertebræ of birds commonly answer this description; though the last one which bears a long free jointed rib (which may or may not reach the sternum) is commonly ankylosed with the sacrum, as *sr*. So few as only *three* hæmapophysis-bearing ribs may reach the sternum. There may also be a long free-jointed rib which "floats" at *both* ends; *i.e.* is articulated neither with the sternum nor with the vertebra to which it belongs, as in the loon, for example. As the dorsal series thus shades insensibly behind into another series, the lumbar (which has no free, nor any *distinct* ribs,—ribs that one would not hesitate to call such), it is best to consider as dorsal or thoracic all those vertebræ, succeeding the last cervical (which is to be determined as explained in the last paragraph), which have *distinct jointed ribs*, whatever the connection or disconnection of such pleurapophyses at either end. On this understanding, one, sometimes two or even three "dorsal" vertebræ ankylose with the pelvic region of the spine. Fixity of the dorsal region being of advantage to flight, these vertebræ are very tightly locked together; not only by the close apposition or even ankylosis of their bodies and processes, but also, in many cases, by ossifications of the tendons of muscles of the back, and coössifications of these with the vertebræ, like a set of splints, till the consolidation of the thoracic is only

surpassed by that of the pelvic region of the spine. Dorsal vertebræ also usually differ a good deal from most cervicals in having shorter bodies, laterally compressed, producing a ridge which runs along their middle line below; in lacking a vertebrarterial canal; in having on each side two articular facets,—one on the body and the other on the transverse process, for the head and shoulder of a rib. They are further distinguished, usually, by having large spinous processes, in the form of high, long, thin, squarish plates, often or usually ankylosed together. Their transverse processes are also very prominent laterally, thin and horizontal, and often ankylosed. More or fewer dorsals may bear large hypapophyses; which, as in the loon, may bifurcate at their ends into two flaring plates. Such processes continue a similar series from the neck, and are in relation to the advantageous action of the muscles (*rectus colli anticus* and *longus colli*) by which the neck is made to straighten out from the lower curve of its sigmoid flexure.

The "Sacrum" of a Bird (Figs. 57 and 60) is commonly considered to be that large solid mass of numerous ankylosed vertebræ in the region of the pelvis, covered in by, and fused more or less completely with, the principal bones of the pelvis, or haunch-bones (*ilia*). But in this consolidation of an extremely variable number (averaging perhaps twelve, but running up to at least twenty, eleven to thirteen being usual) of bones are included vertebræ which in other animals belong to several different sets—dorsal, lumbar, sacral proper, and coccygeal or caudal. We have just seen that one or two, even three, vertebræ, which are dorsal according to the definition agreed upon, may enter into the composition of the "sacrum," being firmly ankylosed therewith, and their long ribs issuing out from underneath the ilia, as shown in Fig. 56, *sr*. Next comes one bone, or a series of several (two to five or more) bones, ankylosed together by their bodies and spinous processes, and also ankylosed with the ilia by means of stout lateral bars of bone sent transversely outward on either side from their respective centra to abut against the ilia. These cross-bars correspond in general form and position with the transverse process of the last true rib-bearing dorsal,—that process against which the shoulder of any developed rib abuts; they are variously considered to be, to represent, or to include, rudimentary ribs; and such difference of view may be warranted by the state of the parts in different birds. However this may be, the bones just described are *lumbar* vertebræ (Lat. *lumbus*, the loin; where such vertebræ are situated in man and other mammals); which certainly possess abortive ribs in some cases. On successive lumbars the cross-bars, whatever their nature, commonly slip lower and lower downward (belly-ward) on the vertebral

bodies, till the last ones are quite down to the level of the ventral aspect of the centrum; these are also commonly the stoutest, most directly transverse, and most nearly horizontal of the series of processes, abutting against the ilia a little in advance of the socket of the thigh-bone. This ends a series of consolidated "sacral" vertebræ which are termed collectively "dorso-lumbar," — all of them anterior to the true *sacrum* of a bird. The *sacrum proper* **(Fig. 57, *s*) consists of those few vertebræ —three, four, or five—from foramina between which issue the spinal nerves that form** the network called the *sacral plexus*. These true sacral vertebræ are ribless, and may be recognised, in a general way, by the absence of anything like the cross-bars above described, issuing from the vertebral centra; though their neural arches send off some small bars or plates to fuse with the ilia. These sacrals proper are at or near the middle of the whole sacral mass. After these come a large number —from five to ten or more—of vertebræ which, from their following the true sacrals, though consolidated therewith and with one another, are considered to belong to what would be the caudal region of other animals, and are hence called "tail-sacrals," *urosacrals* (Gr. οὖρα, tail, Fig. 57, *c*). These continue to send off a series of little plate-like processes from their neural arches, just as the true sacrals do; but, in addition to these, processes are given off from the bodies of the urosacrals, corresponding in position and relation to those which proceed from the bodies of the lumbars, and being apparently of the same morphological character (pleurapophysial). These "riblets" are, however, quite slender, and also oblique in two directions; for instead of being transverse and nearly horizontal, they trend very obliquely backward and upward; they also shorten consecutively from before backward. The cross-bars of the latter urosacrals, however, are stouter and altogether more like those of a lumbar vertebra. The appearances described are those seen from below, or on

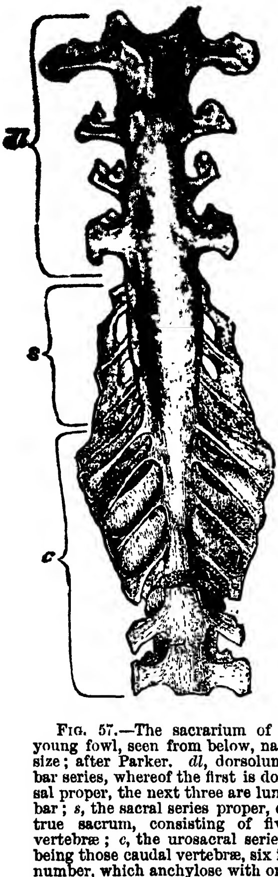


FIG. 57.—The sacrarium of a young fowl, seen from below, nat. size; after Parker. *dl*, dorsolumbar series, whereof the first is dorsal proper, the next three are lumbar; *s*, the sacral series proper, or true sacrum, consisting of five vertebræ; *c*, the urosacral series, being those caudal vertebræ, six in number, which anchylose with one another and with the sacrum.

the ventral aspect. Above, on the back of the pelvis, the line of confluent spinous processes of the dorsolumbars is commonly distinct, separated a little from the flaring lips of the ilia. Such distinct formation may continue throughout the sacral and urosacral regions; oftener, however, the line of spinous process sinks, flattens, and widens into a horizontal plate which becomes perfectly confluent with the ilia along the posterior portion of their extent; such smooth, somewhat lozenge-shaped surface being quite continuous with the superficies of the pelvis, but perforated with more or fewer pairs of intervertebral foramina.—Such is the general character of a bird's complex *sacrarium*, as I name the whole mass of bones that are ankylosed together, including dorsolumbars and urosacrals, as well as sacrum proper. The description is taken chiefly from a raven (*Corvus corax*); the figure from the common fowl, after Parker. The kidneys are moulded into the recesses between the sacral and urosacral vertebræ and in the concavity of the ilia. The general shape of a sacrarium, viewed from below, is fusiform, broadest across the sacral bodies proper or just in front of them, tapering toward either end; the face of the sacrarium is also flattest about the middle, more or less ridged before and behind from compression of the vertebral bodies. It has little if any lengthwise curvature, and that chiefly in the urosacral region, where the concavity is downward. The total number of bones may be less than twelve, or more than twenty. The extensive ankyloses in this region of the spine are in evident adaptation to bipedal locomotion, which requires fixity hereabouts, that the trunk may not bend upon the fulcrum represented by a line drawn through the hip-joints, which are situated about opposite the middle of the sacral mass, as shown by the arrow, *ac*, in Fig. 60.

The Coccygeal, or Caudal Vertebræ (Fig. 56, *clv*) proper, terminate the spinal column. They are called "coccygeal," from the fancied resemblance of the human tail-bones collectively to the beak of a cuckoo (Gr. κόκκυξ, *kokkux*). The caudals are all the *free* bones situated behind the ankylosed urosacrals. The series commonly begins opposite the point where the pelvic bones end; it consists of a variable number of bones, from the twenty long slender ones which the *Archæopteryx* possessed, down to seven or fewer separate ones. The usual number is eight without the pygostyle. They are stunted, degraded vertebræ, whose chief office is to support the tail-feathers: for the leash of nerves which emerge from the spinal canal to form the sacral plexus by so much diminishes the spinal cord that a mere thread is left to penetrate the tail, though the neural arches of all the coccygeals be still pervious. All may be freely movable, as in the American Ostrich (*Rhea*); but in almost all birds only the anterior ones are distinct and vertebra-like, the

rest, to a variable number, being abortive, and melted into that extraordinary affair called the rump-post or *pygostyle* (Gr. πυγή, *puge*, the rump; στῦλος, a post), which may consist of no fewer than ten such metamorphosed tail-bones. It has usually a shape suggesting the share of a plough (see Fig. 56, *py*), but is too variable to be concisely described. The pygostyle supports the tail-feathers; and as these are morphologically one pair to each rectrix-bearing vertebra, the number of tail-feathers may be primarily equal to the number of vertebræ which fuse in the pygostyle. Thus the swan is said to have ten vertebræ in this mass; a wild swan (*Cygnus columbianus*) has twenty tail-feathers. In this view, six should be the usual composition of the share-bone. A bird's tail is really more extensive and lizard-like than commonly supposed; thus the swan, besides its ten in the pygostyle, has seven free caudals, and ten urosacrals—twenty-seven post-sacral vertebræ in all (Huxley). In the raven, the free caudals are six, exclusive of the pygostyle. These all have large flaring transverse processes and moderate spinous processes, and the latter ones are also provided with hypapophyses, some of which are bifurcate. The pygostyle in many birds expands below into a large circular or polygonal disk.

2. THE THORAX: RIBS AND STERNUM

The Thorax (Gr. θώραξ, a coat of mail; in anatomy, the chest; adj. *thoracic*; see Fig. 56) is the bony box formed by the ribs on each side, the breast-bone below, and the back-bone above. In birds it is very extensive, including most or all of the abdominal as well as the thoracic viscera, and its cavity is not partitioned off from that of the belly by a completed *diaphragm*, though a rudimentary structure of that kind is found in the *Apteryx*. The thorax is usually soldered behind to the pelvis by union of one or more pairs of ribs with the ilia; in front it always and entirely bears the *pectoral arch* (see p. 215). The thorax is very movable in birds, by reason of the great length and jointedness of the ribs.

The Ribs (Lat. *costa*, a rib; pl. *costæ;* adj. *costal;* see Fig. 56, *c*, *c'*, *R*, *cr*, *sr*, *u*), as said above, are the pleurapophysial elements of vertebræ, which remain small and ankylosed, or become long and free. In the latter state only are they "ribs" in ordinary language. The one or more cervical ribs, however elongated, and the abortive lumbar and urosacral ribs, are to be excluded from the present description, and have been already considered. *True ribs* are those which belong to the dorsal vertebræ proper, and are jointed in themselves; that is, have articulated *hæmapophyses* (see p. 203), by which they may or do articulate with the sternum. Such true ribs are *fixed*, when they reach from back-bone to breast-bone; *floating*,

when either or neither of these connections is made. Usually the last rib, though bearing a perfect hæmapophysis, does not reach the sternum; in the loon, for example, the last rib floats at *both* ends, having connection neither with vertebra nor sternum; and the two next ribs float at their sternal ends. The perfected ribs are few,—five or six is a usual number, though nine are hæmapophysis-bearing in the loon. The last rib at least is usually *sacrarial*, as it belongs to a dorsal vertebra which is ankylosed with the sacrarial mass; and two, or even, as in the loon, three ribs may likewise issue out from under cover of the ilia. These "sacral ribs" or *sacrocostals* are furthermore distinguished by being devoid of the *epipleural* or *uncinate processes* (Lat. *uncus*, a hook; Fig. 56, *u*) with which other true ribs are furnished, forming a series of splint-bones proceeding obliquely from one rib to shingle over the next succeeding one, and thus increase the stability of the thoracic side-walls. Such splints may be either articulated or ankylosed with their respective ribs; they have independent ossific centres. The upper (pleurapophysial) part of a rib, or "vertebral rib," when perfected, articulates with the side of the body of a vertebra by its head or *capitulum* (Lat. dimin. of *caput*, head), and also with the lateral process of the same vertebra by its shoulder or *tuberculum* (Lat. dimin. of *tuber*, a swelling). In well-marked cases the head and shoulder are quite far apart, the rib seeming prolonged above; either of these vertebral connections may be disestablished, the other remaining, or both may be lost. The lower (hæmapophysial) part of a rib, or "sternal rib," articulates with the side of the sternum by a simple enlargement; the ends of those sternal ribs which thus join the sternum tend to cluster closely together at a part of the breast-bone called its *costal process* (Fig. 58); those which do not make the sternal connection are simply bundled together. Commonly five or six, sometimes four, rarely only three ribs reach the sternum. The ribs are ordinarily as slender and strict as those shown in Fig. 56; but in *Apteryx*, for example, their pleurapophysial parts are expansive and plate-like. They lengthen rapidly from before backward, both in their vertebral and their sternal moieties; these parts meet at angles of decreasing acuteness from before backward; but these angles, as those of the ribs both with vertebræ and sternum, incessantly increase and diminish in the respiratory movements of the chest; all being in expiration more acute, and more obtuse in inspiration.

The Avian Sternum (Gr. στέρνον, *sternon*, the breast; Fig. 56, *S*) is highly specialised; its extensive development is peculiar to the class of birds, and its modifications are of more importance in classification than those of any other single bone. Thereupon it becomes an interesting object. Theoretically it is a collection of

occurs. The extreme case of emargination of the sternum is afforded by the *Gallinæ*, and is highly characteristic of that group. Here the lophosteon is extremely narrow, and fissured deeply away from the metostea, which latter are deeply forked; the arrangement giving rise to two very long slender lateral processes on each side (Figs. 1 and 2, p. 73). The sternum of the tinamou, a dromæognathous bird, is still more deeply emarginated, but the extremely long and slender lateral processes, which enclose an oval contour, are simple, not forked.

In a very few birds there are centres of ossification additional to those above described. In *Turnix*, there are said by Parker to be a pair of centres between the pleurostea, which he names *coracostea*, because related to the part of the sternum with which the coracoids (see p. 216) unite. The same authority describes for *Dicholophus* a posterior median cartilaginous flap having a separate centre, named *urosteon* (Gr. οὖρα, *oura*, tail). In various birds the sternum is eked out in the middle line behind by cartilage which has no ossification.

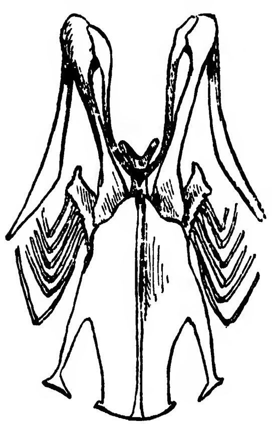


FIG. 58.—Typical passerine sternum, pectoral arches, and sternal ends of ribs; from the robin, *Turdus migratorius*, nat. size; Dr. R. W. Shufeldt, U.S.A. Sternum single-notched, with prominent costal processes and forked manubrium; five ribs reaching sternum, one rib "floating."

The sternum, especially of the higher birds, develops in the middle line in front a beak-like process called the *rostrum* or *manubrium* (Lat. *manubrium*, a handle); its size and shape vary; it is well marked in Passerine birds (Fig. 58); and may be bifurcate at the end and run down the front of the keel some way, as in the raven. The fore border of the sternum is generally greatly convex from side to side, and then in those birds which have prominent pleurostea, produced in angular costal processes. This border is also thickened, and presents on each side a well-marked, smooth-faced groove, in which the expanded feet of the coracoid bones are instepped and firmly articulated. These deep grooves commonly meet in the middle; are occasionally continuous from one side to the other; sometimes each crosses to the other side a little way. The costal processes on each side also have thickened edges, with a series of articular facets for the ribs, which gives this border a fluted or serrate profile. Generally the fore half, or rather less, of the side border of the sternum is thus articular; and it is only such *costiferous* (rib-bearing) extent of sternum which corresponds to the whole body of the bone in a mammal, all the rest being "xiphoid."

The singular carinate sternum of *Notornis*, and the ratite bone of *Apteryx*, are concave crosswise along the front border, and bear the coracoids far apart, at the summits of antero-lateral projections.

A sternum is generally concavo-convex in every direction, bellying downward; somewhat rectangular, it may be long and narrow, or short, broad, and squarish. It is commonly longer than broad, with convex front border, a median beak, which is often forked, prominent antero-lateral corners, pinched-in sides (bulging in tinamou) and indeterminate hind border. The keel usually drops down lowest in front, sloping or curving gently up to the general level behind, with a concave (rarely protuberant) vertical border, and pronounced apex, to which the clavicles may or may not be ankylosed, as they are in a pelican, for instance. In *Opisthocomus* the clavicles ankylose with the manubrium of the sternum. The external surface, both of body and keel, is ridged in places, indicating lines of attachment of the different pectoral muscles. In a few birds, notably swans and cranes, the sternal keel is expanded and hollowed out to receive folds of the windpipe in its interior (see Figs. 99, 100).—But the numberless modifications of the sternum in details of configuration belong to systematic ornithology, not to rudimentary anatomy.

3. THE PECTORAL ARCH

The Pectoral Arch (Lat. *pectus*, the breast; Figs. 1, 2, 56, 58, 59) is that bony structure by which the wings are borne upon the axial skeleton. It is to the fore limb what the pelvic arch is to the hind limb; but is disconnected from the back-bone and united with the breast-bone, whereas the reverse arrangement obtains in the pelvic, which is fused with the sacral region of the spine. Each pectoral arch of birds consists (chiefly) of three bones: the *scapula* and *coracoid*, forming the *shoulder-girdle* proper, or *scapular arch;* and the accessory *clavicles*, or right and left half of the *clavicular arch*. There is also at the shoulder-joint of most birds an insignificant sesamoid ossicle, called *scapula accessoria* or *os humero-scapulare* (Fig. 56, *ohs*); and in many a rudiment of a bone called *procoracoid*, which occurs in reptiles, but in birds is united with the clavicle. From the ribs, the scapula; from the sternum, the coracoid; from its fellow, the clavicle, converges to meet each of the two other bones at the point of the shoulder. The lengthwise scapular arches of opposite sides are distinct from each other; the clavicular arch is crosswise, and nearly always completed on the middle line of the body; by which union of the clavicles the whole pectoral arch is coaptated. The coracoid bears the shoulder firmly away from the breast; the scapula steadies the shoulder against the ribs; the

clavicles keep the shoulders apart from each other. The scapular arch is always present and complete; the clavicular is sometimes defective or wanting. There are two leading styles of scapular arch, corresponding to the ratite and carinate sternum. (1) In *Ratitæ* the axes of the coracoid and scapula are nearly coincident (for the most part in a continuous right line) and ankylosed together; the clavicles are usually wanting, or defective; and the coracoids are instepped on the sternum far apart. (2) In all *Carinatæ* the axes of the coracoid and scapula form an acute or scarcely obtuse angle (Figs. 56 and 59, *sglc*); normally these bones are not ankylosed; perfect clavicles are present, ankylosed with each other, but free from the other bones; and the coracoids are instepped close together. Decided exceptions to these conditions, as in *Notornis*, are anomalous; though incompletion of the clavicles repeatedly occurs, as noted below.

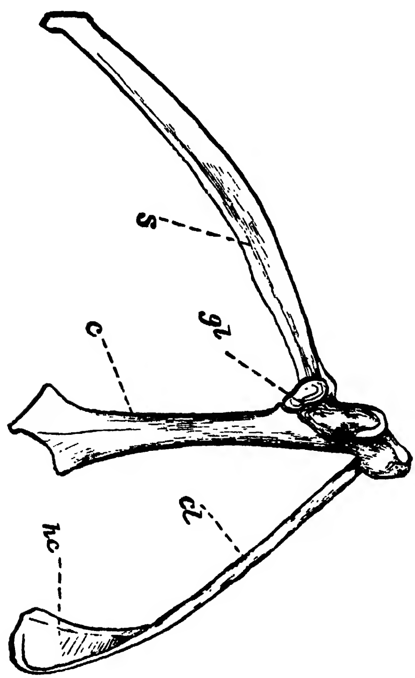


FIG. 59.—Right pectoral arch of a bird, *Pediœcetes phasianellus*, nat. size, outside view; Dr. R. W. Shufeldt, U.S.A. *s*, scapula; *c*, coracoid; *gl*, glenoid, the cavity for head of humerus; *cl*, clavicle; *hc*, hypoclidium. *In situ*, the right end of the figure should tilt up a little; see Fig. 56.

The Coracoid (Gr. κόραξ, *korax*, a crow; εἶδος, *eidos*, form: the corresponding bone of the human subject, which is the stunted "coracoid process of the scapula," being likened to a crow's beak; no applicability in the present case; Figs. 56 *c*, 59 *c*) is a stout, straight, cylindric bone, expanded at each end, extending forward, outward, and upward from the fore border of the sternum to the shoulder. Its foot is flattened and splayed to fit in the articular groove of fore border of the sternum already described; it often overlaps that of its fellow on the median line; is narrower and remote from its fellow in *Ratitæ*. The head of the bone, irregularly expanded, articulates or ankyloses with the end of the scapula, and also usually with the clavicle. It bears externally a smooth

demi-facet, which represents the share it takes in forming the *glenoid* (Gr. γλήνη, *glene*, a shallow pit; Fig. 59, *gl*) *cavity*, which is the socket of the humerus. This articular expansion is the *glenoid process* of the coracoid: the *clavicular process* is that by which the bone unites with the clavicle. The relation between the heads of the three bones (each uniting with the other two) is such that a pulley-hole is formed, through which plays the tendon of the pectoral muscle which elevates the wing. The coracoid is a very constant and characteristic bone of birds.

The Scapula (Lat. *scapula*, the shoulder-blade; Figs. 56, 59, *s*) merits in birds its name of "blade-bone," being usually a long, thin, narrow, sabre-like bone, which rests upon the ribs—usually not far from parallel with the spinal column, and near it; but in *Ratitæ* otherwise. It seldom gains much width, and is quite thin and flat in most of its length; but it has a thickened head or handle, expanding outwards into a *glenoid process* which unites with that of the coracoid to complete the glenoid cavity, and dilated inward to form an *acromial* (Gr. ἀκρώμιον, *akrōmion*, point of the shoulder) *process* for articulation with the clavicle (as it does in man), when that bone exists. The other end is usually sharp-pointed, but may be obtuse, or even clubbed, as in a woodpecker. The scapula is broadest and most plate-like in the penguins, in which birds all the bones of the flipper-like wing are singularly flattened. In *Apteryx* it reaches in length over only a couple of ribs; in most birds, over most of the thorax; and in some its point overreaches the pelvis.

The Clavicles, or Furculum (Lat. *clavicula*, a little key: *furculum*, a little fork; Figs. 56, 59, *cl*), or the clavicular arch, are the pair of bones which when united together form the object well known as the "merrythought" or "wish-bone," corresponding to the human collar-bones. They lie in front of the breast, across the middle line of the body, like a V or U; the upper ends uniting as a rule both with scapula and coracoid. For this purpose, in most birds, the ends are expanded more or less; such expansion is called the *epiclidium* (Gr. ἐπί, *epi*, upon; κλειδίον, *kleidion*, the collar-bone); in Passerine birds it is said to ossify separately, and is considered by Parker to represent the *procoracoid* of reptiles. At the point of union below, the bones often develop a process (well shown in the domestic fowl) called the *hypoclidium* (Gr. ὑπό, *hypo*, under; Fig. 59, *hc*), supposed to represent the *interclavicle* of reptiles. The clavicles are, as a rule, present, perfect, ankylosed together, articulated at the shoulder; in a few birds ankylosed there; in several, there and with the keel of the sternum; in *Opisthocomus* there and with the manubrium of the sternum. In various birds, chiefly Picarian and Psittacine, they are defective,

not meeting each other. They are wanting in *Struthio*, *Rhea*, *Apteryx*, and some *Psittacidæ*. Besides curving toward each other, the clavicles have usually a fore-and-aft curvature, convex forward. In general, the strength of the clavicles, the firmness of their connections, and the openness of the V or U, are indications of the volitorial or natatorial power of the wings. The end of the furculum is hollowed for a fold of the windpipe in the crested pintado.

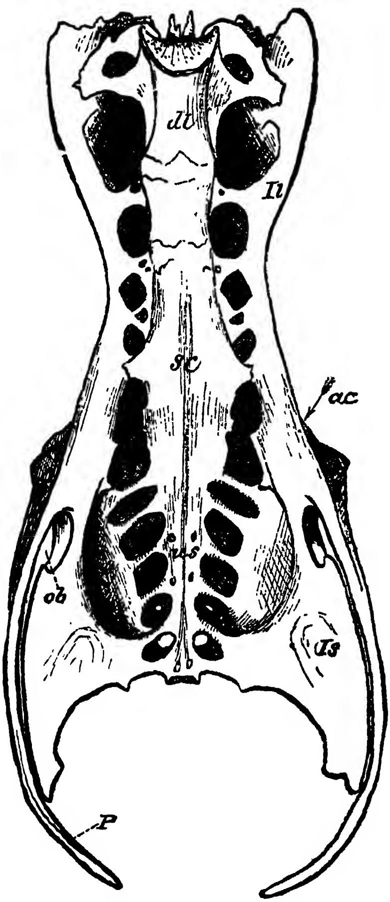


FIG. 60.—Pelvis of a heron (*Ardea herodias*), nat. size, viewed from below; from nature by Dr. R. W. Shufeldt, U.S.A. *dl*, dorsolumbar vertebræ to and including the last one, *sc*; below *sc*, for the extent of the *large* black spaces (opposite the arrow) are the true sacral vertebræ; *us*, urosacral vertebræ (opposite the five oval black spaces; *Il*, ilium; *Is*, ischium; *P*, pubis; *ob*, obturator foramen. The arrow flies into the acetabulum.

4. THE PELVIC ARCH

The Pelvis (Lat. *pelvis*, a basin, Fig. 60) is that posterior part of the trunk which receives the urogenital, and lower portion of the digestive, viscera. It consists of the sacrarium on the middle dorsal line, flanked on each side by the bones of the *pelvic arch*, which supports the hind limb. In vertebrates generally the pelvic basin is completed on the ventral aspect by union (*symphysis;* Gr. *σύν*, *sun*, together; *φύσις*, growth) of the bones from opposite sides. Excepting only *Struthio*, which has a pubic symphysis; and *Rhea*, which has an ischiac symphysis just below the sacral vertebræ, the pelvis of a bird is entirely open below and behind; each pelvic arch ankylosing firmly with the sacral vertebræ to form a roof over the viscera above named. This sacro-iliac ankylosis is commonly coextensive with the confluence of the many vertebræ which make the

sacrarium, that is, from the first dorsolumbar to the last urosacral. The whole roof-like affair looks something like a keelless sternum inverted. The pelvic arch of each side consists of three bones, *ilium*, *ischium*, and *pubis*, which have independent ossific centres, but become firmly consolidated together to form the haunch-bone or *os innominatum*. Each of these bones unites with the other two, somewhere near the middle of the whole affair, at a ring-like structure called the *acetabulum* (Lat. a vinegar-cruet, Fig. 56, *a*; Fig. 60, arrow *ac*), or *cotyloid*, or *coxal* cavity, which all three consequently contribute to the formation of, and which is the socket for the head of the thigh-bone. When free ribs issue from under cover of the pelvis, they are commonly ankylosed with the ilia; and all the abortive pleurapophyses of the lumbar and urosacral vertebræ have likewise iliac ankylosis, as explained in treating of the sacrum. As a whole, the pelvis varies like the sternum in relative length, breadth, and degree of convexity; and especially in the configuration of its posterior border; but few zoological characters are derived from this structure.

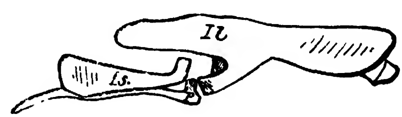


FIG. 61.—Pelvis of *young* grouse, showing three distinct bones. *Il*, *Is*, *P*, ilium, ischium, pubis. In front of former a dorsal vertebra protrudes. (Dr. R. W. Shufeldt, U.S.A.)

Viewed from below, the pelvis is seen to be much hollowed or excavated for the lodgment of the kidneys, and cross-cut into compartments by the sacral rafters; the series of sacral bodies forming a ridge-pole along the middle line. Above, the series of sacral spinous processes represent the ridge-pole; anteriorly, the somewhat spoon-shaped iliac bones are applied, concavity outward, to the dorsolumbars; posteriorly, in the middle line, is a more or less flattened horizontal expansion, and laterally are the more expanded sides of the ischiac roof, finished along the eaves and behind by the slender pubic bone, which commonly projects backward, and inclines toward its fellow of the opposite side. The most prominent formation of the side wall of the pelvis is the thick-lipped smooth articular ring, the *acetabulum*, converted in the natural state into a cup by a membrane. The postero-superior segment of the rim is prominent, to form the *antitrochanter* (Gr. ἀντί, *anti*, against; τροχαντήρ, *trochanter* of the femur) against which the shoulder or trochanter of the femur abuts when the head is in the ring.

It is normal to recent Carinate birds to have the ischium fused with the ilium, however distinct the pubis may remain; but to Cretaceous birds (even *Ichthyornis*), and the existing *Ratitæ*, to have both ischium and pubis distinct in most of their extent.

The Ilium (Lat. *ilium*, haunch-bone; pl. *ilia*; adj. *iliac*; Figs.

56, *I;* 60, 61, *Il*) is the median, most anterior and longest of the haunch-bones, and the only one which extends in advance of the acetabulum. Such anterior prolongation of this bone is the specialty of the avian pelvis: it commonly overlies one or more ribs, and is often overreached by the end of the scapula. It is longest and narrowest and flattest in some of the lower swimmers; the reverse among the highest birds. Its relations and connections have been sufficiently indicated. The bone is almost always separated from its fellow by the sacrum, though the approximation may be close over the back of the pelvis, along the middle line.

The Ischium (Gr. *ἰσχίον, ischion,* the haunch-bone; pl. *ischia;* adj. *ischiadic, ischiatic,* better *ischiac;* Figs. 56, 60, 61, *Is*) lies entirely post-acetabular, or behind the socket which it contributes to form, and composes most of the side-wall of the pelvis thence to the end. It is generally a thin plate-like bone. Among Cretaceous birds and existing *Ratitæ* it only unites with the ilium at and just behind the acetabulum, whence a deep *ilio-ischiac* fissure between the two exists, as in the *young* grouse, Fig. 61; but in ordinary adult birds this fissure is converted into a fenestra or window of large size, just behind the acetabulum, by union of the two bones behind it. This vacuity, whether a notch or a hole, corresponds to the "sacro-sciatic notch" of human anatomy (Fig. 56, *in*). The ischia of opposite sides are distinct, except in *Rhea.*

The Pubis (Lat. *pubis,* bone of the front of the human pelvis where the hair grows at *puberty;* pl. *pubes;* adj. *pubic;* Figs. 50, 60, 61, *P*), beginning at its share of the acetabular ring, is a long slender bone which runs along the lower border of the ischium, sometimes for a short distance only, often for the whole length of the ischium, and usually projecting behind; more or less perfectly parallel with, applied to, or united with, the inferior ischiac border. When separate, a long deep fissure results; when united at the end, a long narrow foramen is formed; when incompletely united in any part of its ischiac continuity, a fissure and a foramen, in the ostrich two foramina, result. All these conditions occur; in any case, such ischio-pubic interval corresponds to the *obturator* foramen (Fig. 56, *o;* Fig. 60, *ob*) of human anatomy; it is greatest in Cretaceous birds and existing *Ratitæ.* The free ends of the pubes may be more or less expanded. In the ostrich only there is a pubic symphysis of the ends of the bones; in the same bird a separate ossicle, situated upon the lower border of the pubes, and called *epipubic,* is considered to represent a "marsupial" bone (Garrod). In various birds, among them the ground cuckoo, *Geococcyx californianus,* the pubis projects a little forward, under the acetabulum: this prominence is the *propubis.* Separation of the pubes is supposed to be for amplification of the pelvic strait to facilitate the passage of the large eggs birds lay.

5. THE SKULL

The Skull of a Bird is a poem in bone—its architecture is the "frozen music" of morphology; in its mutely eloquent lines may be traced the rhythm of the myriad amœbiform animals which constructed the noble edifice when they sang together.[1] The poesy (ποίησις, *poiesis*, a making) of the subject has been translated with conspicuous zeal and success by Mr. W. K. Parker; its zoological moral has been similarly pointed by Professor Huxley; and the young ornithologist who would not be hopelessly unfashionable must be able to whistle some bars of the cranial song—the pterygo-palatine bar at least.

The rapid progress of ossification soon obliterates most of the original landmarks of the skull, fusing the distinct territories of bone in one great indistinguishable area. Thus the brain-box of almost any mature bird is apparently a single solid bone, and most parts of the jaw-scaffolding similarly run together. Aside from the bones of the tongue, which are collectively separate from those of the skull proper; and of the compound lower jaw, which is freely articulated with the rest of the skull; only two or three other bones of the skull, as a rule, are permanently and perfectly free at both ends. These are the quadrate bones—the anvil-shaped pieces by which the lower jaw is slung to the skull; the pterygoids, articulating the palate with the quadrate; and sometimes the vomer. Traces only of distinctness among bones of the face and jaws are usually found; but even such vestiges disappear, as a rule, from among the bones of the brain-box. It is necessary to any intelligent understanding of the construction of a bird's skull, to learn somewhat of its mode of development in the embryonic stage; this being the only clue to the individual bones of which it is composed, and so to any correct idea of its morphology. One theory is, that the skull consists of four modified vertebræ; and the principal bones have been named and described by some writers in terms indicating the elements of a theoretical vertebra. It is true that the skull is segmented, or may be segmented off, like a chain of several vertebræ; that it continues the vertebral axis forward; that it has a *basis cranii* like a series of vertebral centrums; above which rises a segmented neural arch enclosing the great nervous mass, and below which depends a set of bones enclosing visceral parts like a hæmal

[1] Bone-tissue chiefly consists of the aggregated skeletons of *Osteamœbæ*—a kind of unicellular protozoan animals which inhabit in myriads the bodies of nearly all the *Vertebrata*, possessing the faculty of feeding upon phosphate of lime and other earthy matters they find in the blood, and afterward excreting them in the form of multiradiate exoskeletons of their own, collectively forming the whole skeleton of their host.

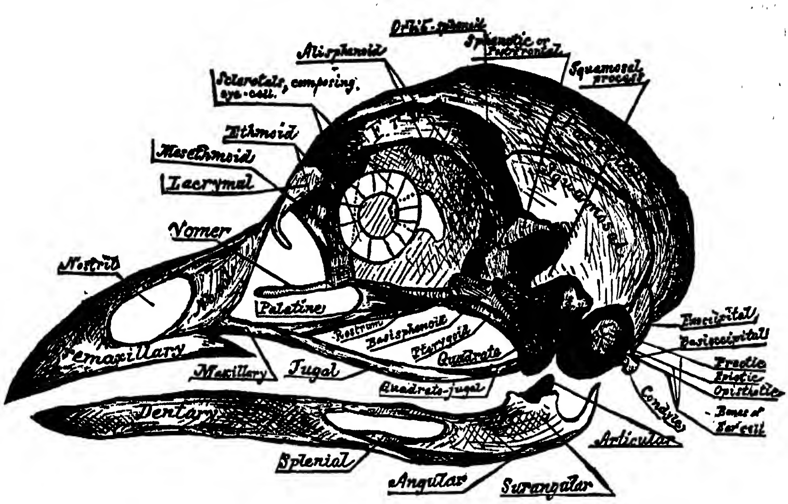


FIG. 62.—Skull of common fowl, enlarged; from nature by Dr. R. W. Shufeldt, U.S.A. The names of bones and some other parts are printed, requiring no explanation: but observe the following points: The distinction of *none* of the bones composing the brain-case (the upper back expanded part) can be found in a mature skull. The brain is contained between the *occipital, sphenoidals, squamosals, parietals,* and part of *frontal;* the *ethmoidals* belong to the same group of cranial bones proper. All other bones, excepting the three *otic* ear-bones, are bones of the face and jaws. The lower jaw, of five bones, is drawn detached; it articulates by the black surface marked *articular* with the prominence just above—the *quadrate bone.* Observe that from this quadrate a series of bones—*quadrato-jugal, jugal, maxillary*—makes a slender rod running to the *premaxillary;* this is the *zygoma,* or *jugal bar.* Observe from the quadrate also another series, composed of *pterygoid* and *palatine* bones, to the premaxillary; this is the *pterygo-palatine bar;* it slides along a median fixed axis of the skull, the *rostrum,* which bears the loose *vomer* at its end. The under mandible, quadrate, pterygoid, and vomer are the only movable bones of this skull. But when the quadrate rocks back and forth, as it does by its upper joint, its lower end pulls and pushes upon the upper mandible, by means of the jugal and pterygo-palatine bars, setting the whole scaffolding of the upper jaw in motion. This motion hinges upon the elasticity of the bones of the forehead, at the *thin* place just where the reference-lines from the words "lacrymal" and "mesethmoid" cross each other. The dark oval space behind the quadrate is the external orifice of the *ear;* the parts in it to which the three reference-lines go are diagrammatic, not actual representations; thus, the quadrate articulates with a large *pro-otic* as well as with the *squamosal.* The great excavation at the middle of the figure, containing the circlet of unshaded bones, is the left *orbital cavity, orbit,* or socket of the eye. The *mesethmoid* includes part of the background of this cavity, shaded diagonally. The upper one of the two processes of bone extending into it from behind is the *post-frontal* or *sphenotic process;* the under one (just over the quadrate) is the *squamosal process.* A bone not shown, the *presphenoid,* lies just in front of the oval black space over the end of *basisphenoid.* This black oval is the *optic foramen,* through which the nerve of sight passes from the brain-cavity to the eye. The black dot a little behind the optic foramen is the orifice of exit of a part of the *trifacial* nerve. The black mark under the letters "on" of the word "frontal" is the *olfactory foramen,* where the nerve of smell emerges from the brain-box to go to the nose. The nasal cavity is the blank space behind *nasal* and covered by that bone, and in the oval blank before it. The parts of the beak covered by horn are only *premaxillary, nasal,* and *dentary.* The *condyle* articulates with the first cervical vertebra; just above it, not shown, is the *foramen magnum,* or great hole through which the spinal medulla, or main nervous cord, passes from the skull into the spinal column. The *basioccipital* is hidden, excepting its condyle; so is much of the *basisphenoid.* The prolongation forward of the basisphenoid marked "rostrum," and bearing the vomer at its end, is the *parasphenoid,* as far as its thickened under border is concerned. Between the fore end of the pterygoid and the basisphenoidal rostrum, is the site of the *basipterygoid process,* by which the bones concerned articulate by smooth facets; further forward, the palatines ride freely upon the parasphenoidal rostrum. In any Passerine bird, the *vomer* would be thick in front, and forked behind, riding like the palatine upon the rostrum. The palatine seems to run into the maxillary in this view; but it continues on to premaxillary. The *maxillo-palatine* is an important bone which cannot be seen in the figure because it extends horizontally into the paper from the maxillary about where the reference line "maxillary" goes to that bone. The general line from the condyle to the end of the vomer is the *cranial axis, basis cranii,* or base of the cranium. This skull is widest across the post-frontal; next most so across the bulge of the jugal bar.

arch. The hindmost cranial segment, the occipital bone, resembles a vertebra in many physical characters, and even in mode of development. But if the serial homology of the skull with the back-bone be real and true, it is so obscured by the extraordinary modifications to which the vertebral elements have been subjected that the fact of such homology cannot be demonstrated; and to interpret the skull as something superimposed upon and morphologically different from the spinal column, is perfectly warranted if not required by the known facts of its constructive development. This is the view taken by the rulers of to-day's science. As already

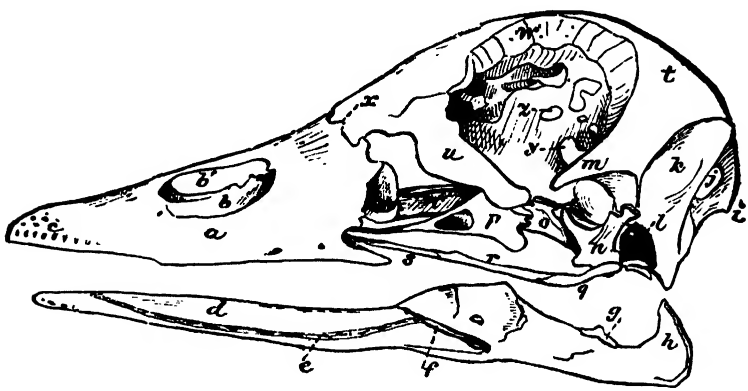


FIG. 63.—Skull of a duck (*Clangula islandica*), nat. size; Dr. R. W. Shufeldt, U.S.A. *a*, premaxillary bone; *b*, partly ossified internasal septum; *b'*, pervious part of nostril; *c*, end of premaxillary, perforated for numerous branches of second division of the fifth cranial nerve; *d*, dentary bone of under mandible; *e*, groove for nerves, etc.; *f*, a vacuity between dentary and other pieces of the mandible; *g*, articular surface; *h*, recurved "angle of the jaw;" *i*, occipital protuberance; *j*, vacuity in supraoccipital bone; *k*, muscular impression on back of skull; *l* is over the black ear-cavity; *m*, postfrontal process; *n*, quadrate bone; *o*, pterygoid; *p*, palatine; *q*, quadratojugal; *r*, jugal; *s*, maxillary; *t*, fronto-parietal dome of the brain-cavity; *u*, the lacrymal bone, immense in a duck, nearly completing rim of the orbit by approaching *m*; *v*, vomer; *w*, supraorbital depression for the nasal gland (see p. 231); *x*, cranio-facial hinge; *y*, optic foramen; *z*, etc., interorbital vacuities.

said (p. 202), the relation between cranial and vertebral parts is rather the analogy of adaptive modification than a true homology of structure.

Before proceeding to describe the mature skull, it will be best to consider its mode of development. In this I shall closely follow Parker, often using the words of that master, and illustrating the early stages of the embryo with figures borrowed from the same safe source. In the fewest words possible, I wish to convey an idea of the embryonic skull up to Parker's "third stage," at which it begins to ossify. Here, however, I will first insert a figure (Fig. 62), kindly drawn for me by Dr. R. W. Shufeldt, of the U.S. Army, which shows most of the cranial bones, and will give the student a

preliminary notion of the "lay of the land." I advise him to contemplate this picture till he has learned the names printed on it by heart, and can apply them to the identification of the parts of the real skull he should have in hand at the same time. He may also meditate on Fig. 63.

Development of the Fowl's Skull (Figs. 64 to 69).—In the chick's head cartilage is formed along the floor of the skull by the fifth day of incubation. This cartilaginous basilar plate is formed on each side of the *notochord*, Fig 64, *c* (Gr. *νῶτον*, *noton*, back; *χορδή*, *chordē*, a chord), a rod-like structure, the primordial axis of the body, around which, along the spinal column, the bodies of the vertebræ are formed, and which runs in the middle line of the floor of the skull as far as the *pituitary space*, *pts*. The basilar plate is the *parachordal* (Gr. *παρά*, *para*, by the side of) cartilage. In this, at the earliest stage, are already planted certain parts of the ear, the *cochlea*, *cl* (Lat. *cochlea*, a snail-shell), and the horizontal one of the three *semicircular canals*, *hsc*. Opposite the end of the notochord, the border of the parachordal plate is notched, 5; this notch afterward forms the *foramen ovale*, for the passage of parts of the *fifth* or *trifacial* nerve. Near the middle line, posteriorly, the plate is perforated for the passage of the twelfth or *hypoglossal* nerve, *q*. At each lateral corner is the separate *quadrate* cartilage, to form the quadrate bone. Anteriorly, the plate connects by a strap or bridge of cartilage, the *lingula*, *lg* (Lat. *lingula*, a little tongue) with the *trabeculæ*, *tr* (Lat. *trabecula*, a little beam), which enclose the *pituitary space*, *pts* (Lat. *pituita*, mucus: no applicability here). In front of this pituitary interval the trabeculæ come together to form an *internasal plate*, which is so arched over downward as to disappear from this view, as seen in Fig. 65, where *fn* is the frontonasal process, and *n* is the future external nostril. After uniting in the internasal plate, the fore ends of the trabeculæ separate and become free; their free ends are the under extremities of this *first visceral arch* (first and only preoral arch).

The same chick's head, now viewed from below, Fig. 65, shows the squarish aperture, *m*, of the future mouth; the three postoral arches, with their respective cartilaginous bars, out of which are to be formed the bones of the jaws and tongue. 1, 2, 3 are the corresponding *visceral clefts*, between the arches; the first of these is to be modelled into the ear-passages (outer and middle ear and Eustachian tube); the others will disappear. The *quadrate* cartilage, *q*, is the same that was seen in Fig. 64; it is already nearly in position, between the hind ends of the scaffolding of the upper and under jaw. The curved *subocular* or *maxillopalatine* bar, *mxp*, developed in the first postoral arch, already indicates anteriorly *palatine*, *pa*, and posteriorly, *pterygoid*, *pg*, parts; it will form the

bones so named, and others of the upper jaw. This subocular bar is an antero-superior part of the first post-oral arch, of which *q* and *mk* are a postero-inferior portion; the cleft of the future mouth is to lie between them. The lower jaw-bone, or *mandible*, is entirely developed from *mk*, its several bones developing around this rod of cartilage, which is called the *Meckelian* cartilage; it is to become

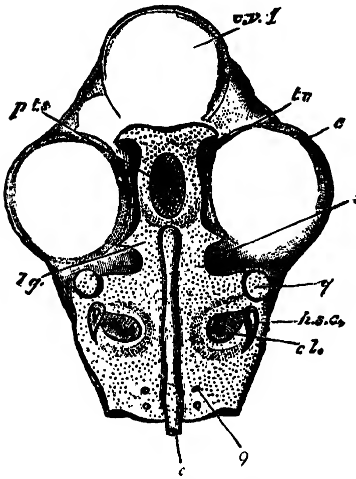


FIG. 64.—Skull of chick, fifth day of incubation, × 9 diameters. Seen from above, the membranous roof of the skull and the brain removed. *cvl*, anterior cerebral vesicle; *e*, eye; *c*, notochord, running through the middle of the basilar plate or parachordal cartilage, in which are already visible the rudimentary ear-parts, *cl*, the cochlea, *hsc*, the horizontal semicircular canal; *pts*, the pituitary space, bounded by *tr*, the trabeculæ, which come together before it to form the frontonasal plate, *fn* in Fig. 65; *lg*, *lingula* or bridge, connecting trabeculæ with parachordal cartilage; 5, notch afterwards becoming foramen ovale for passage of parts of the fifth (trifacial) nerve; 9, foramen for hypoglossal nerve; *q*, separate cartilage forming the future quadrate bone. (After Parker, in *Ency. Brit.*)

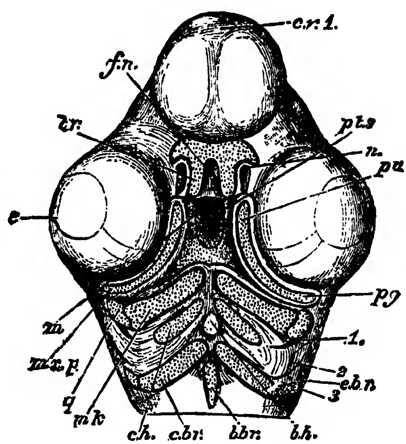


FIG. 65.—Same as Fig. 64, but seen from below. *cvl*, anterior cerebral vesicle; *e*, eye; *m*, mouth; *pts*, pituitary space; *fn*, frontonasal plate; *tr*, ends of the trabeculæ, free again after their union and bent strongly from the original axis of the trabeculæ; *n*, external nostril; *mxp*, subocular bar of cartilage, or pterygopalatine rod, to form *pa*, palatine, and *pg*, pterygoid bone, and other parts of the upper jaw, as the maxillary, jugal, and quadratojugal; *q*, quadrate cartilage, same as seen in Fig. 64; *mk*, Meckelian cartilage, to form lower jaw—these parts are in the first postoral visceral arch; *ch*, ceratohyal, and *bh*, basihyal, of second postoral arch; *cbr*, ceratobranchial, *ebr*, epibranchial, *bbr*, basibranchial, of third postoral arch; the parts of the second and third arch all going into the hyoid bone. 1, 2, 3, 1st, 2d, 3d visceral clefts, whereof the 1st is to be modified into the ear-passages and the others are to be obliterated. (After Parker.)

movably articulated with the bone, the *quadrate*, into which *q* will be transformed. Thus the postero-inferior part of the first postoral arch (second of the whole series of arches) begins in two pieces, one of which is to become the *suspensorium*, or suspender of the mandible, and the other the mandible itself. The rest of the pieces belong to the *second* and *third* postoral arches, and all together make up the very composite *hyoid* bone, or bone of the tongue (Figs. 72, 73, 74). The pieces *ch* and *bh* are in the *second* arch, and form respectively

the *ceratohyal* and *basihyal* bones; the pieces *cbr*, *ebr*, and *bbr* are in the third arch, and form respectively the *ceratobranchial*, *epibranchial*, and *basibranchial* bones. These pieces of the third arch have already outgrown those of the second arch, and they will form the greatest part of the hyoid bone.

In the *second stage*, after the fifth day of incubation, but before any ossification has begun, a vertical section shows the appearances represented in Fig. 66. The parachordal and trabecular cartilages are applied to each other unconformably, the latter rising high between second and third cerebral vesicles to form the posterior pituitary wall, *pcl*, in which the axial skeleton properly ends. There are other changes in the parachordal cartilages. The internasal plate, formed by the union of the trabeculæ in front of the pituitary space, has become a vertical median wall between the olfactory and optic chambers of the right and left sides (*pn* and *eth*, to *ps* and *alc*). This partition, besides forming finally the *interorbital septum* which divides the right and left orbits, will undergo further notable changes in direction, and will develop lateral plates and processes, which will make up the nasal labyrinth and the partition between the cavity of the nose and that of the eye, when any exists. Such lateral developments of the ethmoid plate are the *aliethmoid*, *aliseptal*, and *alinasal*. This plate extends backward in mid-line to the optic foramen, 2, ending in the *anterior clinoid* wall, *acl*, separated from the (parachordal) *posterior clinoid*, *pcl*, wall by the original pituitary space, now the opening through which the carotid arteries, *ic*, enter the brain cavity. Besides ethmoidal parts proper, the plate

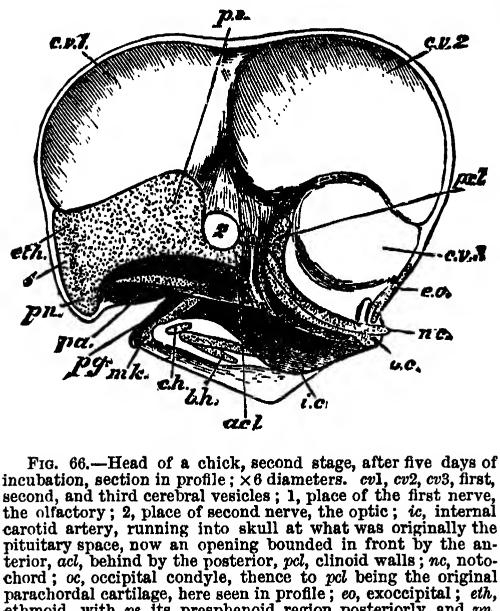


FIG. 66.—Head of a chick, second stage, after five days of incubation, section in profile; ×6 diameters. *cv*1, *cv*2, *cv*3, first, second, and third cerebral vesicles; 1, place of the first nerve, the olfactory; 2, place of second nerve, the optic; *ic*, internal carotid artery, running into skull at what was originally the pituitary space, now an opening bounded in front by the anterior, *acl*, behind by the posterior, *pcl*, clinoid walls; *nc*, notochord; *oc*, occipital condyle, thence to *pcl* being the original parachordal cartilage, here seen in profile; *eo*, exoccipital; *eth*, ethmoid, with *ps*, its presphenoid region posteriorly, and *pn*, prenasal part; this whole plate afterward developing into parts of the nose and the partition between the eyes; *pa*, palatine; *pg*, pterygoid region; *pa* and *pg* reference lines are in the chick's mouth; *mk*, Meckelian cartilage (lower jaw); *ch* and *bh*, ceratohyal and basihyal parts of the hyoid or tongue bone. (After Parker.)

develops at what will be the end of the upper beak a *prenasal cartilage*, *pn*, to become the axis of the beak. The mouth is become already better formed, the axis of its cavity pointing more forward than downward; and great changes are undergoing in parts of the ear at the back corner of the mouth. The quadrate and Meckelian cartilages are assuming much of their true form. The quadrate develops an *orbital* process which extends free into the orbit, and an *otic* process which articulates with the auditory sac and parts of the exoccipital cartilage. The relations at this stage have not been made out in the fowl, but are figured and described from the corresponding stage of the European house-martin (*Chelidon urbica*). In Fig. 67, *mk* is the cut stump of the Meckelian cartilage, of which *ar* is the articular part; *q* is the quadrate, of which a backward process is seen articulating with *teo*, the tympanic wing of the exoccipital. Just below and behind this otic process of the quadrate, exactly in riper embryos is the *fenestra ovalis* in which is fitted the foot of the *stapes* or stirrup-bone of the middle ear, there appears a trowel-shaped projection of cartilage, the handle of which is continuous with the substance of the ear-capsule; the sickle-shaped piece behind which is the tympanic wing of the exoccipital (*teo*). This trowel of cartilage is the upper anterior segment of the hyoidean (second postoral) arch, being to that arch what the pterygo-palatine bar is to the mandibular (first postoral) arch. Several parts of this *stapedial* cartilage are recognised, as named in the fine print under the figure. If the connections of the second postoral arch were completed, as those of the first are, the tongue bone would be slung to the skull as the lower jaw is; but they are not, the tract represented by the dot-line from the *stylohyal*, *sth*, to the *ceratohyal*, *chy*, being, like *ist*, above *sth*, only soft connective tissue. This defect of connection is made up for by the great development of the hyoidean parts of the

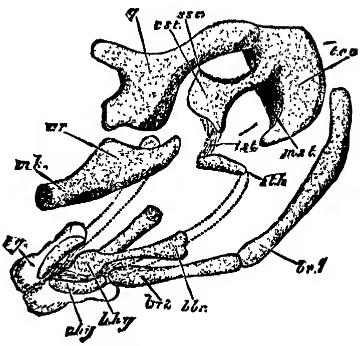


FIG. 67.—The postoral arches of the house martin, at middle of period of incubation, lateral view, ×14 diameters. *mk*, stump of Meckelian or mandibular rod, its articular part, *ar*, already shapen; *q*, quadrate bone, or suspensorium of lower jaw, with a free anterior orbital process and long posterior otic process articulating with the ear-capsule, of which *teo*, tympanic wing of occipital, is a part; *mst*, *est*, *sst*, *ist*, *sth*, parts of the suspensorium of the third postoral arch, not completed to *chy*; *mst*, mediostapedial, to come away from *teo*, bringing a piece with it, the true *stapes* or *columella auris*; the oval base of the stapes fitting into the future *fenestra ovalis*, or oval window looking into the *cochlea*; *sst*, suprastapedial; *est*, extrastapedial; *ist*, infrastapedial, which will unite with *sth*, the stylohyal; *chy* and *bhy*, ceratohyal and basihyal, distal parts of the same arch; *bbr*, *br* 1, *br* 2, basibranchial, epibranchial, and ceratobranchial pieces of the third arch, composing the rest of the hyoid bone; *tg*, tongue. (After Parker.)

third post-oral arch, *br* 1 and *br* 2, which retain the tongue-bone in position, without however articulating it with the skull. The hand of the trowel of cartilage soon segments itself off from the ear-capsule, bringing away with it a small oval piece of the periotic wall, which piece is the true stapes, and the oval space in which it fits is the *fenestra ovalis* leading into the inmost ear (the *cochlea*). The broad part of the trowel-blade is the extrastapedial part, on which the *membrana tympani*, or ear-drum, will be stretched. The stylohyal, *sth*, will join the extrastapedial plate, and the afterward chondrified band of union will be the *infrastapedial*, *ist.* (Figs. 71, *st*, and 83.)

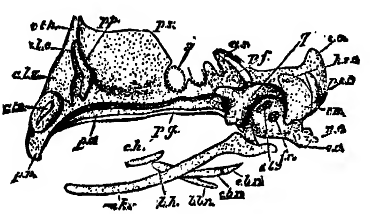


FIG. 68.—Skull of chick, second stage, in profile, brain and membranes removed to show cartilaginous formations, × 4 diameters. *eth*, ethmoid, forming median nose-parts and interorbital septum; developing lateral parts, as *ale*, aliethmoid, *als*, aliseptum, *aln*, alinasal, *pp*, partition between nose and eye; *pn*, pre-nasal cartilage; *ps*, presphenoidal part of mid-ethmoid; 2, optic foramen; *as*, alisphenoid, walling brain-box in front; *pf*, post-frontal, bounding orbit behind; *pa*, *pg*, palatine and pterygoid; *q*, quadrate; *so*, supra-occipital; *eo*, exoccipital; *oc*, occipital condyle, borne upon basioccipital, and showing *nc*, remains of notochord; these occipitals bound the foramen magnum, and *eo* expands laterally to form a tympanic wing, circumscribing the external auditory orifice behind and below; *hsc*, *psc*, horizontal and posterior vertical semicircular canals of ear; *fr*, *st*, fenestra rotunda and fenestra ovalis, leading into inner ear, latter closed by foot of the stapes; *mk*, *ch*, *bh*, *bbr*, *cbr*, *ebr*, parts of jaw and tongue, as named in Figs. 65, 66, and 67. (After Parker.)

Returning now to the chick's head, which we left to examine the intricate ear-parts at the proximal end of the second post-oral arch, we see by Fig. 68 how rapidly the parts are shaping themselves at the end of this second stage of development. This figure shows the cartilaginous skull, in which no trace of ossification has appeared, excepting in the under mandible. The brain and membranous parts of the cranium have been removed. The roof of the skull never becomes cartilaginous. bone there growing directly from the membrane; and the whole of the chondro-cranium, as shown in the figure, is one continuous cartilaginous structure (like the whole skull of an adult shark or skate), excepting the parts of the post-oral arches, which are separate. The auditory capsule is environed by occipital cartilage, *eo*, stretching over the back of the skull, and by wing-like growths (*alisphenoids*, *as*) which wall most of the brain-box in front. The high orbito-nasal septum is a continuous vertical plate of cartilage, upgrowing from the tract of the conjoined trabeculæ. Lateral developments of this ethmoidal wall, in front, are divided into several recognisable parts, *ale*, *als*, *aln*, the latter being the external nostril; *pp* is a transverse partition between the orbital and nasal chambers. The nasal cartilages ultimately become much convoluted to form the nasal labyrinth, among the convolutions of which will be the superior and inferior turbinal cartilages, in addi-

tion to those already noted. The ethmoidal wall ends behind at *ps*, the presphenoidal region, where the brain-case begins; below and behind, it is deeply notched for the *optic* foramen, 2. The pituitary space forms a circular foramen, through which the carotid arteries enter. The site of the orbit of the eye is bounded behind and below by the post-frontal process of the alisphenoid wing, *pf* of *as*. The pterygopalatine rod is seen along the under border of the skull, *pg* and *pa*. The quadrate, *q*, has acquired nearly its shape, and the rest of the mandibular and hyoidean parts are clearly dis-

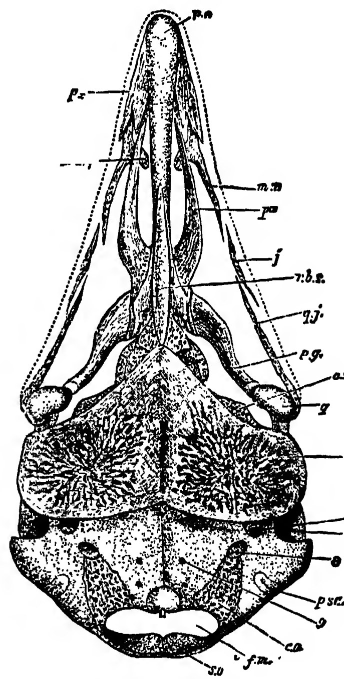


FIG. 69.—Skull of chick, third stage, viewed from *below*, × 6⅔ diameters. *pn*, prenasal cartilage, running behind into the septum nasi; on each side of it the premaxillary, *px*, of which the (inner) palatal and (outer) dentary processes are seen (the upper nasal process hidden); *mx*, the maxillary, developing inner process, the maxillopalatine, *mxp*; *pa*, the palatal, well formed, articulating behind with *rbs*, the sphenoidal rostrum, its thickened under border, the parasphenoid; this will bear the vomer at its end when that bone is developed; *j*, jugal, joining *mx* and *qj*, the quadratojugal, joining *j* and *q*, the quadrate; *mx* to *q*, the jugal bar or zygoma; *pg*, the pterygoid, making with *pa* the pterygopalatine bar, joining *q* and *px*; *bt*, the basitemporal, great mat of bone from ear to ear, underflooring the skull proper, as *rbs*, a similar formation, does further forward; *ic*, outer end of carotid canal, to run between the *bt* plate and true floor of skull, and enter brain cavity at original site of pituitary fossa (Figs. 64, 66, *ic*); *ty*, tympanic cavity—external opening of ear; *as*, alisphenoid, bounding much of brain-box anteriorly, and orbital cavity posteriorly; *psc*, posterior semicircular canal of ear, in opisthotic bone, which will unite with the spreading *eo*, exoccipital, which will reach the condyle shown in the middle line, above the foramen magnum, *fm*, completed above by *so*, supraoccipital; 8, foramen lacerum posterius, exit of pneumogastric, glossopharyngeal and spinal accessory nerve; 9, exit of hypoglossal nerve, in basioccipital. (After Parker.)

played, *mk*, etc. The proximal hyoidean element, *st*, is freed from the periotic cartilage, leaving the fenestra ovalis (see last paragraph). Below the general outline, *pa* to *oc*, is not shown a mat of soft tissue, in which are to be developed the *basitemporal* and *parasphenoid* bones which underfloor the whole skull,—the former making a plat between the ears, Fig. 69, *bt*, the latter forming the thickened under edge of the *rostrum* of the skull *rbs*.

At the third stage, about the middle of the second week of incubation, the cartilaginous parts already described are neatly finished, and the skull is beginning to *ossify*. The occipital parts are well

formed; the condyle is perfect; the foramen magnum is circumscribed by the ex- and supra-occipitals, *eo* and *so*, Fig. 69. Investing bones, formed in membrane without previous cartilage, are becoming apparent. The basitemporal, *bt*, and parasphenoid, *rbs*, are engrafting upon the base of the skull. The *prenasal cartilage*, *pn*, now at its full growth, is beginning to decline; on each side of it is formed a three-forked bone, the premaxillary, *px*, having superiorly nasal, and laterally palatal and dentary processes. This bone is to grow to great size, forming most of the upper beak, and starving out the maxillary, which in mammals is the principal bone of the upper jaw. The palatal, *pa*, and pterygoid, *pg*, bones are ossified, and the quadrate, *q*, is ossifying. Between the premaxillary and the quadrate are the bones forming the *zygoma*, or jugal bar, developed in the outer part of the maxillopalatine bar of the earlier embryo. They are the weak *maxillary*, *mx*, with its ingrowing process, the *maxillopalatine* bone, *mxp*; next the *jugal*, *j*; then the *quadratojugal*, *qi*; the whole forming an outer lateral rod from quadrate to premaxillary, like a duplicate of the pterygopalatine rod from the same to the same.

Among occurrences of later stages are to be noted the development in membrane in the middle line below of the *vomer*, borne upon the end of the rostrum; the roofing in of the whole skull by the *parietal*, *squamosal*, *frontal*, and *nasal* bones; the completion of the *periotic bones* as the *proötic*, *epiotic*, and *opisthotic*, which form the *otic capsule*, or *otocrane*; the development of *lacrymal bones*, bounding the orbits of the eyes in front. Absorption of the middle wall of cartilage between the nasal and orbital cavities nicks off the nose parts from those of the orbit (Fig. 70, between *ntb* and *eth*); and certain changes in the orbital septum develop the *orbitosphenoids*. Very nearly all the bones of a bird's skull having thus been accounted for, we may next consider them in their adult condition. Reference should be made to Figs. 62, 63, 70, 71.

The Occipital Bone (Figs. 62, 70, 71) forms the back part of the floor of the skull, and lower part of the back wall of the skull; neither its boundaries nor its composition are visible in adult skulls. It is formed by the *basioccipital*, *bo*, below in the middle line; the *supraoccipital*, *so*, above in the middle line; the *exoccipital*, *eo*, on either side. These bound the *foramen magnum* (Fig. 69, *fm*), where the nerve-mass makes its exit from the cavity of the cranium into the tube of the spinal column. At the lower part of the foramen is the protuberant occipital condyle (Figs. 68, 71, *oc*), borne chiefly upon the basioccipital, but to the formation of which the exoccipitals also contribute; the latter flare widely on each side, into the tympanic wings, which bound the external auditory meatus behind. The true basioccipital is mostly covered by the underlying secondary bone,

the *basitemporal* (Figs. 69, 70, *bt*), which extends from one tympanic cavity to the other, and more or less forward in the middle line to the sphenoidal rostrum. Openings to be observed in the occipital region, besides the great foramen, are those for the hypoglossal nerve, 9, near the condyle; for the parts of the vagus nerve, 8, more laterally, and the carotid canal, *ic:* also, above the foramen magnum, openings for veins, sometimes of great size, as in Fig. 63, *j*.

The Parietals (Figs. 62 and 70, *p*, 71).—Proceeding up over the brain-box, the next bones are a pair of parietals between the occipital behind, the frontal before, and the squamosal beside; but their limits are rarely if ever to be seen in adult skulls. They are relatively small in birds; simply squarish plates, bounded as said, coming together in the upper mid-line, or sagittal suture.

The Frontals (Figs. 62 and 70, *f*, 71), originally paired, soon fuse together, and with surrounding bones of the skull, though maintaining some distinction from those of the nose and jaw. These roof over much of the brain cavity, close in much of it in front, and form the roof and eaves of the great orbital sockets. Anteriorly in the middle of the forehead line the feet of the nasal process of premaxillary are implanted upon the frontal, usually distinctly; more laterally, the nasal bones are articulated or ankylosed; this fronto-naso-premaxillary suture forming the frontofacial hinge (Fig. 63, *x*), by the elasticity or articulation of which the upper jaw moves upon the skull, when acted on by the palatal and jugal bars. In the midst of the forehead the two halves of the frontal sometimes separate, as they do in the fowl, allowing a little of the mesethmoid to come to the front. In the middle line, underneath, the frontals fuse with whatever extent there may be of the mesethmoid which forms the lengthwise interorbital septum, and often a crosswise partition between the orbital and nasal cavities. To the antero-external corners of the frontal are articulated or ankylosed the lacrymals. The *postfrontal process*,[1] morphologically the postfrontal or sphenotic bone, bounds the rim of the orbit behind; it is usually quite prominent. The frontal rim of the orbit in many birds shows a crescentic depression (very strong in a loon and many other water-birds; Fig. 63, *w*), for lodgment of the supraorbital gland, the secretion of which lubricates the nasal passages. The cerebral plate of the frontal is often imperfectly ossified, showing large fenestræ besides the regular openings for the exit of nerves

[1] There is apparently some ambiguity in the use of the term "postfrontal" process by different authors. It would appear that this process, bounding the rim of the orbit behind, may be a projection of the frontal bone, and therefore strictly a postfrontal process. Or that, as said by Owen for *Rhea*, it may be a separate bone, and therefore properly a *postfrontal bone*. Or, again, that it may have nothing to do with the frontal bone, but belong to the alisphenoid, as a process of the latter or a separate ossification; in which case it would be properly the *sphenotic*. In no event has it anything to do with the *squamosal* process lettered as such in Fig. 62.

which are always found at the back of the orbit. Viewed from above, the frontal is vaulted and expanded behind, over the brain cavity, then pinched more or less, sometimes extremely narrow over the orbits, then usually somewhat expanded again at the frontofacial suture. The extent of the frontal between the orbits and face, in the lacrymal region, is very great in the duck family, as see in Fig. 63.

The Squamosal (Lat. *squama*, a scale; Figs. 70, 71, *sq*) bounds the brain-box laterally, between occipital, parietal, frontal, and sphenoidal bones, its distinction from all of these being obliterated in adult life. It is situated near the lower back lateral corner of the skull, forming some part of the cranial wall just over the ear-opening, and a strong eaves for that orifice. It is firmly united also to the bones of the ear proper, and receives the larger share of the free articulation which the quadrate has with the skull. It often develops a strong forward-downward spur, the squamosal process (Fig. 62), looking like a duplicate postfrontal process; between these two is the *crotaphite depression*, corresponding to the "temporal fossa" of man, in which lie the muscles which close the jaws. It scarcely or not enters into the orbit, the adjacent part of the orbit being alisphenoidal.

The Periotic Bones (Gr. περί, *peri*, about; οὖς, ὠτός, *ous*, *otos*, the ear; Fig. 70) are those that form the *petrosal bone* (Lat. *petrosus*, rocky, from their hardness), or bony periotic capsule, containing the essential organ of hearing. When united with each other and with the squamosal, they form the very composite and illogical bone called "temporal" in human anatomy. There are three of these otic bones,—an anterior, the *proötic;* a posterior and inferior, the *opisthotic* (Gr. ὄπισθε, *opisthe*, behind) and a superior and external, the *epiotic*. They can only be studied in young skulls, upon careful dissection; they do not appear upon the outside of the skull at all, excepting a small piece of the opisthotic, which there fuses indistinguishably with the exoccipital. But some part of these bones is seen on looking into the cavity of the outer ear, and if the fenestra ovalis can be recognised, it determines a part of the boundary between the proötic and opisthotic bones, while the fenestra rotunda lies wholly in the latter. The cavity of the periotic bone is hollowed for the labyrinth of the internal ear, including the cochlea, which contains the essential nervous organ of hearing, and the three semicircular canals—so much of them as does not invade surrounding bones. In the young fowl's skull viewed internally (Fig. 70), Parker figures a very large proötic portion (*po*) of the periotic, perforated by the internal auditory meatus (7) for the entrance from the brain of the auditory nerve; below and behind the proötic a small opisthotic (*op*), in relation with the exoccipital, upon the surface of which it also appears, outside (Fig. 69, at *psc*), and with

which it blends; a very small epiotic centre (*ep*), between the proötic and supra-occipital; and the anterior semicircular canal (*asc*) embedded in the latter. In Dr. Shufeldt's figure the otic elements are merely noted diagrammatically. According to Huxley's generalisation, the epiotic is in special relation with the posterior semi-

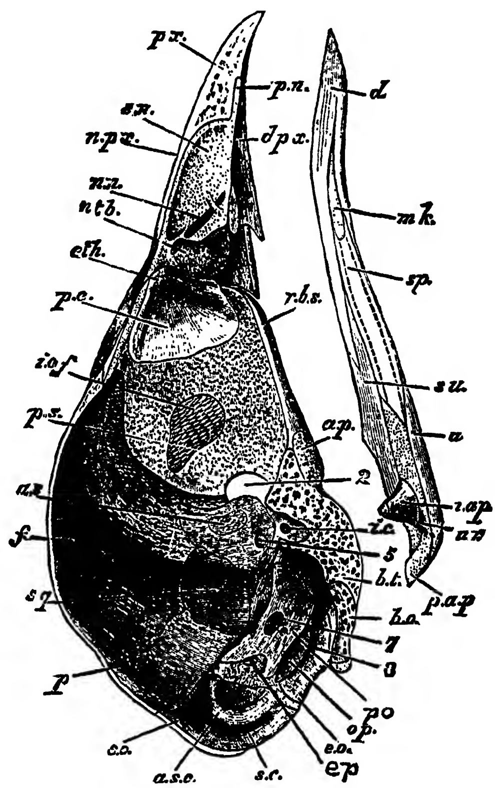


FIG. 70. — Ripe chick's skull, longitudinal section, viewed *inside*, × 3 diameters; after Parker. In the mandible are seen: *mk*, remains of Meckelian rod; *d*, dentary bone; *sp*, splenial; *a*, angular; *su*, surangular; *ar*, articular; *iap*, internal articular process; *pap*, posterior articular process. In the skull: *pn*, the original prenasal cartilage, upon which is moulded the premaxillary, *px*, with its nasal process, *npx*, and dentary process, *dpx*; *sn*, septonasal cartilage, in which is seen *nn*, nasal nerve; *ntb*, nasal turbinal; the reference line crosses the *craniofacial suture*, the face parts and cranial parts being nearly separated here by the nick seen in the original cartilaginous plate; *eth*, ethmoid; *pe*, perpendicular plate of ethmoid, which will spread nearly throughout the dotted cartilaginous tract in which it lies, to form nearly all the interorbital septum; transverse thickening (in some birds) below the reference line *eth* will form the prefrontal or orbitonasal septum; *iof*, interorbital foramen; *ps*, presphenoidal region, just above which is the orbitosphenoidal region; 2, optic foramen; *as*, alisphenoid, with 5, foramen for divisions of the 5th (trifacial) nerve; *f*, frontal; *sq*, squamosal; *p*, parietal; *so*, superoccipital; *asc*, anterior semicircular canal; *sc*, a sinus (venous canal); *ep*, epiotic; *eo*, exoccipital; *op*, opisthotic; *po*, proötic, with 7, meatus auditorius internus, for entrance of 7th nerve; 8, foramen for vagus nerve; *bo*, basioccipital; *bt*, basitemporal; *ic*, canal (in original pituitary space, Fig. 66, *ic*) by which carotid artery enters brain cavity; *ap*, basipterygoid process; *ap* to *rbs*, rostrum of the skull, being the parasphenoid bone underflooring the basisphenoid and future perpendicular plate of ethmoid. (The scaffolding of the upper jaw not shown, excepting *px*, etc.)

circular canal; the proötic with the anterior vertical canal, between which and the foramen ovale (5) for the lower divisions of the trifacial nerve it lies. That part on which the inner foot of the quadrate is implanted is proötic. Below the drooping eaves of the squamosal, before the flaring wing of the exoccipital, and behind the quadrate bone, is the always decided and considerable cavity of

the ear, bounded pretty sharply by the squamosal and exoccipital rim, sloping with less distinction in front toward the orbital cavity. In this auditory hollow may be seen several openings: the *meatus* or proper ear-passage, through which, in one direction, a bristle may be passed to emerge at or near the middle line of the base of the skull, about the root of the basisphenoidal rostrum. Such a passage is through the *first visceral* cleft of the early embryo, modified into *meatus auditorius* and *Eustachian tube*, which latter communicates with the back part of the mouth. Besides the other ear-passages proper, may be found other openings of air-passages leading into the interior diploic tissue of bones of the skull, and especially into the lower jaw-bone. The ear-parts are immensely developed in owls, in many species of which they are unsymmetrical, that is, not sized and shaped alike on right and left sides of the head.

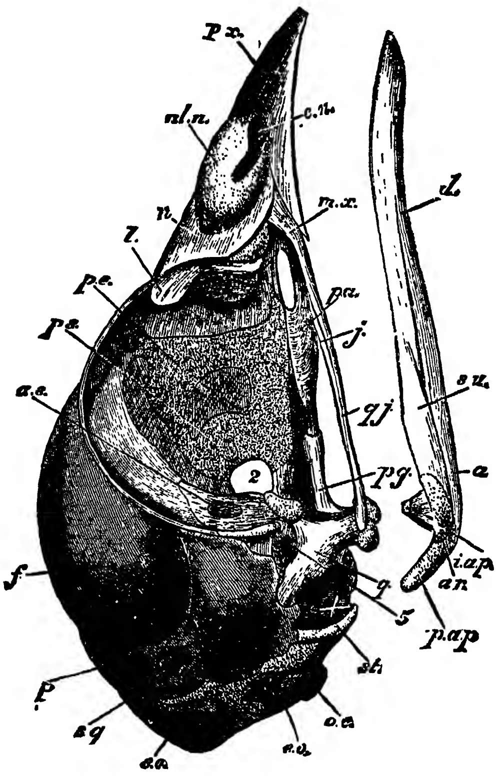


FIG. 71.—Ripe chick's skull, in profile, × 3 diameters; after Parker. *px*, premaxillary; *aln*, alinasal cartilage; *en*, septonasal; *n*, nasal bone; *l*, lacrymal; *pe*, perpendicular plate of ethmoid, as in Fig. 70; *ps*, presphenoidal region; *as*, alisphenoid; *f*, frontal; *p*, parietal; *sq*, squamosal; *so*, superoccipital; *eo*, exoccipital; *oc*, occipital condyle; *st*, the cross-like object, the stapes, whose foot fits fenestra ovalis, see Fig. 83; *q*, quadrate; *pg*, pterygoid; *qj*, quadratojugal; *j*, jugal; *pa*, palatine; *mx*, maxillary. In the mandible: d, dentary; *su*, surangular; *a*, angular; *ar*, articular; *iap*, internal angular process; *pap*, posterior angular process. 2, optic foramen; 5, foramen ovale, for inferior divisions of the 5th nerve. (Compare Fig. 70.)

The Sphenoid (Gr. σφήν, *sphen*, a wedge; εἶδος, *eidos*, form; Figs. 62, 70, 71) is a compound bone, not easy to understand as it occurs in birds, as much of it is hidden from the outside, some of it is very slightly developed, and all of it is completely consolidated

with surrounding bones in the adult. It is wedged into the very midst of the cranial bones proper, with its body in the middle line below, next in front of the basioccipital, and its wings spread on either side in the orbital cavity. A sphenoid consists essentially of the *basisphenoid*, or main part of the bone (Fig. 62); the pair of *alisphenoids* or "wings," one on either side (Figs. 70, 71, *as*); the obscure *presphenoid* (*ps*) in the middle line in front of and above the main body; and the pair of small *orbitosphenoids*, which are in fact the wings of the presphenoid. The body is usually covered in by the underflooring of the basitemporal; it is a flat triangular plate, produced more or less forward in the middle line as the *basisphenoidal rostrum*, or beak of the skull. This *rostrum* (*ap* to *rbs* in Fig. 70) is an important thing. It forms, in fact, the central axis of the base of the skull; with the mesethmoid plate the inferior border of the interorbital septum, usually thickened by the underflooring of the *parasphenoid* (Fig. 70, *rbs*). The rostrum often bears on each side a *basipterygoid process* (*ap*),—a smooth facet with which the pterygoid articulates. These processes may be very strong, and far back on the basisphenoid body, when the pterygoids articulate with them near their own posterior ends, as in the struthious birds and tinamous (Fig. 75, *btp*); or they may be further along on the rostrum, and the pterygoids then articulate near or at their fore-ends. The rostrum may be produced far forward, beyond the maxillopalatines and vomer even, as in an ostrich; or it may bear the vomer at its end; or may be embraced by forks of the vomer; the palatines may glide along it, or be remote from it on either side. In any event, whatever its production, whatever part may be ethmoidal, or basisphenoidal, or parasphenoidal thickening, pterygo-faceting, etc., this "beak" of the basisphenoid is always in the axis of the base of the skull, and at the bottom of the interorbital plate; it may be horizontal, or obliquely ascending forward; and the variety of its relations with the pterygopalatine and vomerine mechanism furnishes important zoological characters, as we shall see when we come to treat of palatal structure particularly. Just at the base of the beak, where it widens into the main body of the bone, may commonly be seen, coming from between the sphenoidal body and the lip of the basitemporal underflooring, the orifices of the Eustachian tubes, and often also the anterior ends of the carotid canal. If a bristle, passed into a questionable foramen here, comes out of the ear, it has gone through the Eustachian tube; if it comes out below the ear, on the floor of the skull, outside, it has run in the carotid canal. The extent of the *alisphenoids* (Figs. 70, 71, *as*) cannot be determined in old skulls. They lie at the back lower border of the orbital cavity, closing in most of the brain-box that is

not foreclosed by the frontal bone. You will always find at the back of the orbit, close to the mid-line, and rather low down, the very large holes which transmit the optic nerves from the brain to the eye; these are the *optic foramina* (any Figs., 2); alisphenoid should not extend in front of these orifices. A little below and behind the optic foramina, and much more laterally, not far from the quadrate itself, is a considerable foramen, quite constant, for transmission of the inferior divisions of the *fifth* (*trigeminal* or *trifacial*) nerve. This is the *foramen ovale* (any Figs., 5); it is either *in* the alisphenoid, or between that bone and the proötic; it must not be mistaken for one of the several smaller holes, usually seen close about the optic foramen, which transmit the three nerves (*oculimotor*, *pathetic*, and *abducent*) which move the muscles of the eyeball; these holes being collectively about equivalent to the *foramen lacerum anterius* of human anatomy. Parts about the optic foramen, before and above, are presphenoidal (Figs. 70, 71, *ps*) and orbitosphenoidal; but they are obscure to all but the embryologist, and furnish no zoological characters.

The Ethmoid (Gr. ἠθμός, *ethmos*, a sieve; from the way it is perforated in the human species; Fig. 62) is the bone of the mid-line of the skull, in front of the sphenoidal elements and below the frontal; it is in special relation with the olfactory nervous apparatus, or sense of smell. This is not an easy bone to "get the hang of" in birds. Referring to Figs. 66, 68, *eth*, the student will see in the early embryo a high thin plate of cartilage, the *mesethmoid* cartilage, which is developing lateral processes to form the convoluted walls of the nasal passages. By the uprising and forth-growing of the prenasal cartilage, the mesethmoidal plate is tilted backward, as it were, under the frontal. Next, by absorption of tissue just opposite the future craniofacial suture, the plate is nicked apart, the portion in front of the nick elaborating the nasal chambers, which usually remain cartilaginous, and the portion behind this nick becoming the permanent plate, Fig. 70, *eth*, *pe*, to which the name *mesethmoid* or mid-ethmoid is more strictly applicable. Practically, a bird's ethmoid is chiefly the interorbital septum, in vertical mid-line between the orbits, with such flange-like processes or lateral plates as may be developed to form an *orbitonasal* septum separating the eye-socket from the nose-chamber. In general, the permanent ethmoidal plate becomes nearly coincident with this orbital wall, and pretty well cut off from the osseous or cartilaginous developments, when any, in the nasal cavities. It is then fairly under cover of the frontal, with which, as with the sphenoidal elements posteriorly, it becomes completely fused. When this interorbital septum is fully developed, it completely divides the right and left orbital cavities, and its lower horizontal border, fused with the

basisphenoidal rostrum, may like the latter be thickened by bearing its share of the parasphenoidal splint. Oftener, however, this lower border slopes upward and forward, from the sphenoidal base to the roof of the skull about the site of the craniofacial suture; and usually the septum is incomplete, having a membranous fenestra somewhere near its middle (Fig. 70, *iof*). Along the upper border of the mesethmoid plate, or just in the crease between it and the overarching frontal, may usually be seen a long groove, which, beginning behind at the *olfactory foramen* of the brain-box, conducts the thence-issuing olfactory nerve to the nasal chambers. Sometimes there is another such groove, from a foramen near by in the sphenoidal parts, which similarly traces the course of the ophthalmic (first) division of the trifacial nerve. Occasionally, as in the fowls, the two halves of the frontal bone separate a little at the extreme forehead, allowing the mesethmoid plate there to come up flush with the outer surface of the skull.

In some birds, as the low ostrich, for example, the original mesethmoidal cartilage-plate does not nick apart into orbital and nasal moieties, but ossifies as a continuous sheet of bone, dividing right and left halves of the skull far towards the point of the beak (see Fig. 75, beyond *R* to *Pmx*). A nasal septum, separated from the orbital septum, may persist to ossify; forming, as in the raven, a vertical plate separate from all surroundings, and liable to be mistaken for a free *vomer* (see Fig. 79, where the reference line *v* goes to it, instead of to the truncate vomer); or, as in many birds, a plate variously ankylosed with its surroundings. But these formations, as well as the various *turbinal* (Lat. *turbo*, a whorl) scrolls and whorls formed in this part of the skull, belong rather to the organ of smell than to the skull proper.

The Cranial Bones proper are all those thus far described, excepting the nasal ossifications just noted, which belong to the first preoral arch; and the stapedial parts of the ear, which belong to the hyoidean apparatus (second postoral arch). Intermediate in some respects between the proper cranial bones and

The Facial Bones proper is the Vomer.—By "facial bones," as distinguished from "cranial" bones, is meant the entire bony scaffolding of the upper and lower jaws, and of the tongue,—parts developed in the preoral or maxillary, and first, second, and third postoral, or mandibular, hyoidean proper, and branchial, arches.

The Vomer (Lat. *vomer*, a ploughshare; Figs. 62, 63, 75 to 80, *v*) was considered, by those who held the vertebral theory of the skull, to be the body of the foremost (fourth from behind—the basioccipital, basisphenoid, and presphenoid being the other three) cranial vertebra. So far from having any such morphological significance,

it is one of the late secondary bones, developed, if at all, apart from the general make-up of the skull, as a special superaddition underlying the ethmoidal region, as the parasphenoid and basitemporal underlie the skull farther back. Its character is extremely variable in the class of birds, though usually constant in the several natural divisions of the class,—a fact which confers high zoological value upon this anomalous bone. A vomer is a symmetrical mid-line bone of the base of the skull, found if at all at or near the end of the rostrum. It is originally double, *i.e.* of right and left paired halves. These halves persist distinct in the woodpeckers, and are remote from each other, one on each side of the mid-line (Fig. 80). The vomer is wanting entirely in the Columbine birds, as the pigeons and some of their allies, as the sand-grouse (*Pteroclidæ*) and bush-quails (*Hemipodiidæ*) of the old world, and in certain of the true *Gallinæ*. Its connections are various. It may be borne free upon the end of the rostrum. It may be applied like a splint by a grooved upper surface to the under side of the rostrum, and so fixed there; or, in such situation, it may glide along the rostrum according to the movements of the palatal parts with which it may connect. Thus, in the ostrich (Fig. 75), it saddles the rostrum below, and is joined by the maxillopalatines. Or, it may be united with separate ossifications, the septomaxillaries, which in some birds bridge across the palate (Fig. 80). The commonest case is its deep bifurcation behind (Fig. 79), each fork uniting with the palate bone of its own side, and sometimes also with the pterygoid. Such is usually the fixture of the bone behind, and it then rides along as well as simply bestrides the rostrum. The anterior end of the vomer may be perfectly free, projecting into the floor of the nasal chambers (Figs. 62, 77), or the fore end may be variously steadied or connected with maxillary processes (Fig. 78). When free in front, and often when not, the vomer is a simple share-like plate, more or less expanded vertically, quite thin laterally, and "spiked," *i.e.* running forward to a point; under these circumstances it may or may not bifurcate behind, and be there attached to the palatines or not. But the commonest case of vomer, shown by the great Passerine group, which comprise the majority of recent birds, is different from this, the vomer being in front thickened, flattened and expanded laterally, and connected with nasal cartilages and ossifications (alinasals and turbinals). Such a vomer, deeply cleft behind to join the palatals, is endlessly diversified in the configuration of its fore end, which may be notched, lobbed, clubbed, etc. The *general case* of such a vomer is indicated by the expression "vomer truncate in front," as distinguished from the simply pointed or "spiked" vomer. (For further details see description of the several patterns of palatal structure, beyond.)

The Quadrate Bone (Lat. *quadratus*, squared; Figs. 62, 63, *n*, 64, 65, 68, 69, 71, *q*, 75, *Qu*), with which we may begin the jaw-bones proper, is the suspensorium of the lower jaw,—the perfectly constant and characteristic bone by means of which the mandible proper articulates with the skull. Its rudiment is seen in the earliest embryos, at the corners of the primordial parachordal cartilages. It belongs to the mandibular (first postoral) arch, of which it is the proximal element. Its general morphology has caused much dispute. From the fact that in birds one of its functions is to support, in part, the tympanum of the ear, it has been identified with the *tympanic* bone of mammals,—that which in man forms the bony tube of the external auditory meatus. The view now generally accepted is, that the bird's quadrate represents, certainly in part, probably in whole, the little bone of the middle ear called the *malleus* in mammals. However this may be, the quadrate of a bird bears the proximal ends of *both* jaws, carrying their final (posterior) articulation up to the squamosal and petrosal bones. Thus, the foot of the quadrate forms the free hinge of the lower jaw, and also movably articulates the back end of both the zygomatic and the pterygopalatine bars or "arcades." The head of the quadrate freely articulates with the squamosal, just in front of the tympanic cavity, which it thus bounds in front; and there is usually a shoulder which furthermore articulates with the anterior periotic bone, the proötic. Struthious birds do not have these two distinct facets. A long *pedicle* or *orbital process* extends forward, inward, and upward in the orbit; this non-articular handle is for advantageous muscular traction. So circumstanced, the quadrate is a stocky bone, of a shape reminding one of an anvil; it rocks freely to and fro upon its cranial socket, pulling and pushing upon the whole maxillary and mandibular mechanism, with such effect that when the lower jaw drops, the zygomatic and palatal bars are automatically shoved forward, tending to make the upper jaw rise, and so increase the opening of the mouth. Such mobility of the upper jaw automatically with the movement of the lower is very free in parrots, whose craniofacial connections are quite articular in character; it is well shown also in ducks; and probably nearly all birds have some such motion of the upper jaw upon the skull. In nearly all birds, the mandibular articular facet of the quadrate is divided by a lengthwise impression into inner and outer protuberances, or condyles, fitting corresponding depressions on the articular face of the lower jaw; in some birds the articular surface is single. The zygomatic articulation with the quadrate is made by the balled end of the quadratojugal socketed in a cup at the outer side of the mandibular facet (with various minor modifications in different birds). The palatal articulation is made by a little condyle of the

quadrate, at the inner side of the main facet, socketed into the cupped end of the pterygoid (with minor modifications).

The Quadratojugal and Jugal Bones (Lat. *jugum*, a yoke; Figs. 62, 63, *q*, *r*, 69, 71, *qi*, *j*) form most of the outer arcade—the *jugal* or *zygomatic* bar—leading from the quadrate bone to the beak. The quadratojugal is posterior, reaching a variable distance forward; at its fore end it is obliquely sutured to the jugal, a splint-rod which carries the bar forward to the maxillary bone, with which it is in like manner obliquely sutured. The whole affair is almost always a slender rod, which, with its fellow of the opposite side, forms the outermost lateral boundary of the skull for a great distance. It corresponds in general with the "zygomatic arch" of a mammal, which is made up of a "zygomatic process of the squamosal" and a malar or "cheek-bone." The whole zygomatic arch, including the maxillary bone itself, is developed from the outer part of the primordial pterygopalatine bar (see Fig. 65). In parrots the zygoma is movably articulated before as behind.

The Maxillary Bone (Lat. *maxilla*, upper jaw-bone; Figs. 62, 63, *s*, 69, 71, 75, *mx*), forming so much of the upper jaw of a mammal, is in birds greatly reduced, being starved out by the predominant premaxillaries which form most of the upper beak. The shape of this stunted bone varies too much to be concisely described. Its connections are, ordinarily, with the jugal behind, by a long slender splint-like process, and with the premaxillary and usually the nasal bones in front and externally. Internally, it may or may not connect with the palatal and vomer. The zoological interest of this bone centres in certain inward (palate-ward) processes, often its most conspicuous parts, and apparently corresponding to the plate which in a mammal roofs the hard palate anteriorly. Though these are mere processes from the main maxillary, they are so distinct and important that they are commonly described as if they were independent bones, under the name of the *maxillopalatines*. They are flange-like or scroll-like plates, or large spongy masses of delicate bone-tissue,—endlessly varied in configuration and context (see the various figures of base of skull, *mxp*, beyond, where the palatal patterns are described). Certain other inward maxillary processes, which may or may not unite with the vomer, and so bridge over the palate, are called *septo*-maxillaries (Fig. 80, *smx*); and in some woodpeckers yet other palatal processes appear (Fig. 80, *pmx*).

The Pterygoid Bones (Gr. πτέρυξ, *pterux*, wing; εἶδος, *eidos*, form; Figs. 62, 63, *o*, 65, 66, 68, 69, 71, 80, *pg*, 75 to 79, *Pt*). Returning now to the quadrate, and going along the inner arcade, we first encounter the *pterygoid*,—a generally rod-like, but variously twisted, crooked, or expanded bone, which makes the connection between the quadrate behind and the palate bone before. The

pterygoid is always freely jointed at both ends; its posterior quadrate articulation has been noted above; its anterior connection is usually by little nipper-like claws by which it "catches on" to the hind end of the palatine. In the ostrich (Fig. 75, *Pt*) the pterygoid expands into a scroll-like plate; but its rod-like shape is usually preserved. Besides passing very obliquely inward as it goes forward from the wide-apart quadrates to the narrow rostrum in the axis of the skull, the pterygoid often bellies or elbows inwards in its course to join the basisphenoidal beak, and be movably articulated therewith. In the majority of birds there is no such rostral articulation, or the pterygoid only touches the rostrum at its fore end, where it joins the palatal. In many, however, special *articular facets*, called *basipterygoid processes* (Fig. 70, *ap*), are developed on the rostrum for the pterygoids to abut against and glide over. In Carinate birds, excepting the tinamous (*Dromæognathæ*), these processes are forward on the beak, and the pterygoids articulate at or near their own fore ends, as well shown in the fowl or duck (Figs. 77, 78, *Pt*). In Ratite birds and tinamous, the basipterygoids are very long, flaring transverse processes, far back on the rostrum, at the sphenoidal base, and the pterygoids articulate therewith at or near their own posterior ends (Figs. 75, *Btp*, and 76).

The Palatal or Palatine Bones (Lat. *palatum*, roof of the mouth; Figs. 62, 63, *p*, 65, 66, 68, 69, 71, 77, 78, 80, *pa*, 75, 76, 79, *Pl*) are a pair, approximately parallel and near the mid-line, forming that part of the "hard palate" or roof of the mouth which is not constructed by the palatal processes of the maxillaries, or by the vomer. They are nearly always long thin bones, among the most conspicuous parts when the dried skull is viewed from below. Sometimes, as in the ostrich (Fig. 75, *pl*), they are remote from the axis of the skull and only connected in front with the maxillaries and maxillopalatines. In many birds they skip the maxillary parts in going forward to be fused with the premaxillaries; in most, probably, they form anterior connections in one or another fashion with palatal parts both of maxillaries and of premaxillaries. Behind, they always correctly articulate with the pterygoid. The mid-line connections made in most Carinate birds (not in *Dromæognathæ*) are variously with the vomer, with the rostrum, with each other, or some or all of these relations at once. A long deeply-cleft vomer may by its posterior forks attach itself to the whole palatal mid-line, excluding the palatals from the rostrum; less extensive attachment of the same kind may permit the palatals to touch each other and the rostrum posteriorly, while cutting them off anteriorly; also, a non-cleft vomer may attach itself to the posterior extremity of the palatals, and bear them off the rostrum. The whole hard palate may fuse into an indistinguishable mass; and in almost any

case the relations of the palatals to each other and their connections afford some of the most valuable zoological characters of great groups of birds. (Details figured and described beyond.) Though very variable in configuration, as well as in connections, certain parts of a palatal may usually be recognised, and conveniently named for descriptive purposes. Anteriorly, in the great majority of birds, of whatever technical kind of palatal structure, the palatals are simply prolonged as flat strap-like or lath-like bars running past the maxillary to the premaxillary region; and such simple band-like character may be preserved behind. Ordinarily, however, the palatals expand posteriorly, becoming more or less laminar; and in this plate-like part three surfaces may usually be recognised. One, more or less horizontal, flaring outward, is the *external lamina*. It is well shown in a Passerine or Raptorial bird, where the *postero-external angle* (between the outer border and the posterior end) of the palatal is well marked, or may be acutely produced; there is no such lamina in a fowl, where the palatals are for the most part slender and rod-like. An internal plate, more or less vertically produced to make the mid-line rostral or vomerine connection, is the *superior internal lamina*, or *mediopalatine process;* very strong, for example, in a fowl, where it forms all the expanded part of the bone, and ends anteriorly as a sharp *inter-palatine spur*. The mediopalatine is probably to be regarded as the main body of the bone, being the most axial part, of the most extensive and varied connections. A third lip or plate of the palatal is the *inferior internal lamina*, looking downward; it is generally very evident, but in a duck or fowl is reduced to a mere ridge, indicating where the superior internal and external laminæ meet. A duck's palatals are quite different in appearance from those of most birds, all the posterior parts just distinguished been reduced and constricted, while the fore ends, running abruptly into the hard-boned beak, are much expanded horizontally (Fig. 78). The postero-external angles of the palatal (formed by the external lamina), even when much produced, may not reach as far back as opposite the pterygopalatine articulation; or they may surpass these limits, and when they do, such backward prolongation is called *postpalatine*, the palate being considered to end at the pterygoids. In like manner, the maxillary processes of the palatals, or the palatal strips as prolonged into the premaxillary region, are called *prepalatines*. The inner posterior process, by which the palatine is articulated with the pterygoid, is its *pterygoid process*.

The Premaxillary Bones (Figs. 62, 63, *a*, 69, 70, 71, 80, *px*, 75 to 79, *pmx*), also called **Intermaxillaries**, form most of the upper beak, attaining enormous development in birds, and reversing the usual relative size of premaxillary and maxillary. Mainly deter-

mining as they do the form of the upper mandible, their shapes are as various as the bills themselves of birds; but their generalised characters can be easily given. Each premaxillary, right and left, forms its half the bill; the two are always completely fused together in front, commonly preserving traces at least of their original distinction behind. They are commonly called one bone, *the* premaxillary. Each is a triradiate or 3-pronged bone; one upper prong, the most distinct, called the *nasal* or *frontal process*, forms with its fellow the culmen (Fig. 26, *b*) of the bill. These processes, side by side, run clear up to the *frontal* bone in birds, driving the nasal bones apart from each other. Such a *median* fronto-premaxillary suture, with lateral frontonasal and nasopremaxillary sutures, is highly characteristic of birds,—an arrangement probably exceptionless. Two other horizontal prongs on each side, extensively distinct from the frontal process in most birds, but less separate from each other, run horizontally along the side and roof of the mouth for a variable distance. These horizontal prongs are an *external* or *dentary* process (Fig. 80, *ppx*), forming the tomium (Fig. 26) of the bill, and reaching back to join the dentary part of the maxillary; and an *internal* or *palatal process* (Fig. 80, *ppx*), running along the commencement of the bony palate. With this latter the anterior ends of the palatal bones unite,—either on the side toward the mid-line of the beak, or between the palatal and dentary processes, as in a woodpecker (Fig. 80). Great laminar expansions inward of these palatal parts of the premaxillaries roof the hard part of the mouth anteriorly, though there is usually a vacancy between the premaxillary hard palate and that formed farther back by the maxillopalatines and palatines. The posterior extremities at least of the frontal processes of the premaxillaries are commonly distinguishable from each other as well as from the frontal and nasal bones—in fact, these fronto-naso-premaxillary sutures are among the most persistent of all. The divergence of the frontal from the palatal and dentary processes bounds the external nostril in part, the circumscription of that orifice being completed by the prongs of the nasal bones. The superficies of the premaxillary bone, like that of the dentary piece of the lower jaw-bone, is commonly sculptured with the impressions of the vessels and nerves which ramify beneath the horny integument; and in birds with very sensitive bills, as a snipe or duck, the end is perforated sieve-like with little holes, into which the skin shrinks in drying, producing the familiar pitted appearance (Fig. 63, at *c*).

The Nasal Bones (Figs. 62, 71, *n*) might have been described next after the *frontals*, as they continue forward the general roofing of the skull; but are conveniently considered in the present connection, being in birds rather "facial" than "cranial." They are of

large size, and pronged,—one fork, the *superior process*, being applied for a variable distance along the outer side of the frontal process of the premaxillary, the other, *inferior*, descending to or towards the dentary border of the maxillary or premaxillary, or both; the divergence of these two processes bounding the nostril behind. The base of the nasal, uppermost and posterior, ankyloses (usually) or sutures (often) or articulates (as in parrots) with the antero-external border of the frontal bone; its frequent collateral connections being with the lacrymal or ethmoid, or both of these. The nasals are very variable in shape, as well as in the extent of their connections. When expansive, they may wall in much of the nasal cavity, as well as bound the nostrils. These latter openings, as far as their bony boundaries are concerned, are usually much more extensive than they seem to be from the outside, being greatly contracted by membrane and integument. Ordinarily, each forms a large vacuity, which the descending prong of the nasal bone separates from a similar vacancy between itself and the lacrymal, the lacrymal in turn interposing between this and the orbital cavity. The descending process of the nasal, in fact, is a marked object at the side of the base of the upper mandible of most birds, though slight or rudimentary in the Ratitæ. A character of the nasals has been employed in classification by Mr. Garrod. A bird having the bones as above generally described, with moderate forking, so that the angle of the fork, bounding the nostrils behind, does not reach so far back as the fronto-premaxillary suture, is termed *holorhinal* (Gr. ὅλος, *holos*, whole; ῥίς, ῥινός, *rhis*, *rhinos*, nose; Fig. 62). But in the *Columbidæ*, and in a great many wading and swimming birds, whose palates are cleft (*schizognathous*), the nasal bones are *schizorhinal* (σχίζω, *schizo*, I cut); that is, cleft to or beyond the ends of the premaxillaries; such fission leaving the external descending process very distinct from the other, almost like a separate bone. Pigeons, gulls, plovers, cranes, auks, and other birds are thus split-nosed. The value of the character, except as an auxiliary, is doubtful.

The Lacrymal (Lat. *lacryma*, a tear; from the relation of the human bone to the tear-duct; Figs. 62, 63, *u*, 71, *l*) is one of several splint-like membrane-bones of the skull, having little intimacy of relation with the general morphology of the cranium, though quite constant in birds, and often very conspicuous. It is situated at or near the anterior outer corner of the orbit, near the nasal but behind that bone; sometimes ankylosed, sometimes very loosely attached, oftener firmly sutured with the frontal; and may also have connection with the nasal and ethmoid. It is generally a claw-like affair, depending from the front outer corner of the frontal, and consequently bounding the orbit anteriorly; it may be variously

twisted, crooked, hooked, etc. It is singularly elongated and distorted in the ostrich. In the duck tribe, in which the lacrymo-frontal region of the skull is greatly elongated, the lacrymal has coextensive attachment to the frontal bone, and is broadly laminar, with a downward process; in some ducks bounding at least a fourth of the orbital brim, and almost completing the circle by extending toward the very protrusive postfrontal process, as in Fig. 63, *u*. In some parrots, the rim of the orbit is completed below, and even sends a bony bar to bridge over the temporal fossa behind the postfrontal. In some birds, the lacrymal is quite free, and even in more than one free piece. The *os uncinatum*, or *os lacrymo-palatinum*, would appear to be a palatine bone distinct from the lacrymal; it has been observed in the *Musophagidæ* and many other picarian birds, in *Tachypetes*, and certain *Procellariidæ*. The lacrymal bone seems to be the principal relic, in birds, of a set of splint-bones which lie about the edges of the orbits in many *Sauropsida*. Another is the postfrontal or sphenotic, usually a process of the frontal, often a separate ossification. In some birds, as various *Raptores*, there are one or more loose supraorbital plates of bone, serving to eke out the brim of the orbits; thus forming the "orbital shields" so prominent in many hawks, and causing their eyebrows to project. Were such a chain of splint-bones complete (lacrymal, superorbitals, postfrontal, and squamosal, to quadrate), it would form an arcade of bones, *over* the orbit, like the actual zygomatic arch (maxillary, jugal, quadratojugal, to quadrate) which lies under the orbit; and such a double series is very perfectly illustrated in many of the *Sauropsida* below birds.

Other special ossifications have been described in some birds, but I am obliged to pass them over. I have already far exceeded intended limits, and have yet to describe the mandibular and hyoidean arches, and the zoological characters of the palate as a whole.

The Mandible, or Lower Jaw-Bone (Figs. 62, 63, 70, 71) is a collection of bones developed in the first postoral visceral arch. Each half of the compound bone (right and left) consists normally of *five* bones, which become immovably ankylosed, but traces of the original distinction of which commonly persist for an indefinite period,—in some birds throughout their lives. In an embryo whose skull has passed to the cartilaginous stage, a long slender rod of cartilage appears in the first postoral visceral arch; this is *Meckel's cartilage*, or the *Meckelian rod* (Figs. 65, 66, 68, 70, *mk*), so named after a famous anatomist. Around this rod, which subsequently disappears, the several bones of the mandible are developed. The anterior one of these is the *dentary* (*d*), forming the scaffold of the horny part of the external under mandible. It usually unites by

ankylosis, sometimes only by suture, with its fellow of the opposite side. This union in the middle line is the *symphysis* (Gr. σύν, *sun*, with; φύσις, *phusis*, growth). The line of union is externally the *gonys* (see *antè*), the length and other characters of which are determined by the mode of symphysis, as is the general shape of the tip of the lower mandible. The union generally makes an angular Λ, but may be an obtuse ∩; the symphysis is very short and imperfect, as in a pelican, for instance, or the opposite, as in a woodpecker and a multitude of birds. Behind the dentary, each ramus of the jaw continues with pieces called *splenial*, *angular* and *surangular* (*sp*, *a*, *su*); there is often a fenestra between them, by imperfection of bony union, as shown in Fig. 62 or 63, *f*, which also sufficiently indicates the relations of these parts. The articulation of the jaw with the quadrate bone is furnished by a fifth piece called *articular* (*ar*) from its function. As a whole the mandible is a pronged bone, forking with a variable degree of divergence from its obtuse or acute point, sometimes quite parallel-sided, as in a duck, oftener very open; such prongs may be straight, or variously curved or bent either in the vertical or the horizontal plane; are generally stout and stanch, sometimes so slender as to be quite flexible. The articular part, always expanded horizontally, presents a smooth irregularly cupped superior surface for reception of the protuberances of the foot of quadrate. In general, this concave articular surface is divided into an inner and outer cup separated by a protuberance, corresponding to similar inequalities of the opposing surface of the quadrate. Cupping of the mandibular articulation is characteristic of birds as compared with mammals, in which latter the lower jaw has always a knobbed articular surface (condyle). In many birds the angle of the jaw is prolonged back of the articulation as a *posterior articular process* (Fig. 63, *h*, 70, 71, *pap*), which may be long, slender, and upcurved, as is well shown in a fowl, duck, or plover. Such birds are said to have the "angle of the mandible recurved;" the opposite condition is "angle truncated" (cut off). Usually also, an *internal angular process* (Figs. 70, 71, *iap*) is produced inward from the articular part of the jaw, as in the fowl or duck. Between the dentary and articular parts, the ramus of the jaw is usually vertically produced as a thin raised crest, which, when prominent, is called the *coronoid process*; it corresponds to the strong process so called in a mammal, and relates to the advantageous insertion of the temporal or masseteric muscles which effect closure of the jaw. It is scarcely evident in the fowl (Fig. 62), but well marked in the duck (Fig. 63, over *f*). At the back of the articular surface is the *pneumatic* foramen for entrance of air, when any; on the inner surface of the ramus, about the splenial bone, is the opening conveying the vessels and nerve.

The Hyoid Bone (Gr. letter *ὗ*, *hu* = hy, *εἶδος*, *eidos*, form; Figs. 65-68, 72-74) is the skeleton of the tongue; a very composite structure, consisting of several distinct bones, developed in the second and third postoral visceral arches (see Fig. 65, where *ch* and *bh* are the original elements of the second arch, making the *basihyal*[1] and *ceratohyal* bones, and *bbr*, *cbr*, and *ebr*, are the original elements of the third arch, making the *basibranchial*, *ceratobranchial*, and *epibranchial* bones). The whole affair is somewhat Λ- or ∩-shaped, lying loosely, point forward, between the forks of the lower jaw, with its long slender prongs curving up behind the hind head more or less; but it is not definitely connected with any other bones of the skull. The connection which exists between the hyoid and other cranial bones in a mammal is in birds broken by non-development of certain links of bone developed in the mammalian second postoral arch, as the stylohyal, epihyal, etc.; though birds have a rudimentary stylohyal, at least in the embryo, among the several proximal parts of the second arch which form the intricate bones within the ear-passages (Fig. 67). The visible parts of a bird's hyoid are usually: the body of the bone, *basihyal* (*bh*, and Fig. 72, *c*), single and median, commonly quite short and stocky, sometimes long and slender. The basihyal bears in front a pair of *ceratohyals* (*ch*; not shown in Fig. 72, where they have been absorbed in *b*) usually movably articulated with the basihyal. They commonly appear as little "horns" or processes of the next piece, the *glossohyal* (Fig. 72, *b*) or bone chiefly supporting the substance of the tongue. It may be a stout and apparently single bone, as that of the goose figured; but oftener appears as a pair of slender bones, side by side, whose backward ends are the ceratohyals. The glossohyal may or may not bear at its fore end a cartilaginous tip, as in Fig. 72, *a*. All the

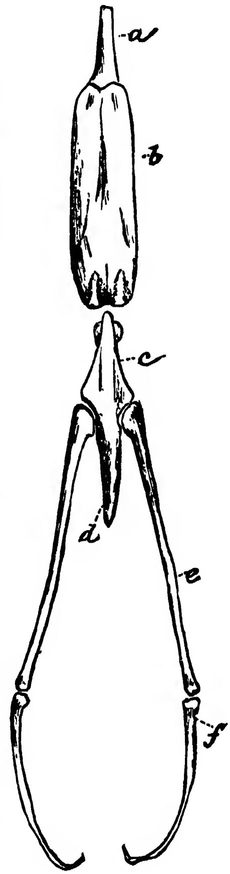
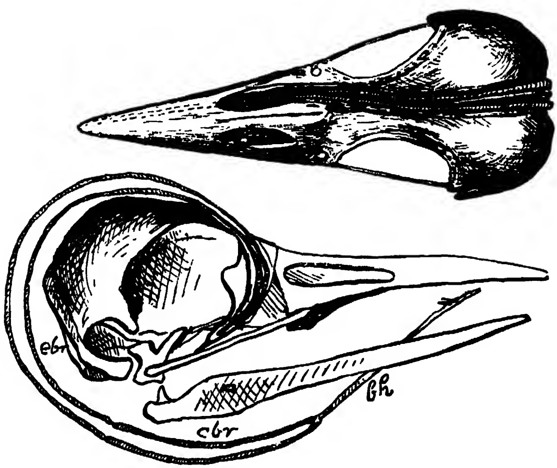


FIG. 72.—Hyoid bones of a goose, nat. size; by Dr. R. W. Shufeldt, U.S.A. *a*, cartilaginous end-piece of *b*, the great glossohyal, which has absorbed or replaced ceratohyals or "lesser cornua"; *c*, basihyal, movably articulated with *b*, and combined completely with *d*, basibranchial, commonly called "urohyal;" *e*, ceratobranchial; *f*, epibranchial; *e* and *f* are together known as "thyrohyals," or "greater cornua."

[1] *Basihyal*, etc. The word *hyal*, used only in composition, means the same as

foregoing are hyal, *i.e.* belonging to the second visceral arch; the following are branchial, of the third arch: The *basibranchial* (*bbr*; Fig. 72, *d*) is a single median piece, projecting backward from the basihyal, with which it may be perfectly consolidated, as it is in the figure, or separately articulated; it may be wanting; it is usually tipped and prolonged backward with a thread of cartilage. The basibranchial is oftener called "urohyal," but had better be allowed its strict morphological name. On either side, the basihyal bears the separately articulated *ceratobranchials* (*cbr*; Fig. 72, *e*), long slender bones diverging as they pass backward, and bearing upon their ends the *epibranchials* (*ebr*; Fig. 72, *f*), which finish off the



FIGS. 73, 74.—Under Fig. side view of a woodpecker's (*Picus*) skull, showing the long slender basihyal (*bh*), bearing slight elements at its fore end, no uroyhal, and extraordinarily long thyrohyals (*cbr*, *ebr*) curving up over back of skull and curling together around orbit of the right eye. Upper Fig. top view of skull of *Colaptes*, showing thyrohyals running along the skull and into right nostril to end of the bill. (Dr. R. W. Shufeldt, U.S.A.)

hyoid bone behind, or may be in turn tipped with cartilaginous threads. The cerato- and epibranchials together are badly called the "thyrohyals," and in still more popular language the "greater cornua" or "horns" of the hyoid. All these bones vary in different birds in size and shape and relative development; the branchial elements are the most constant in their length and slenderness. The whole hyoid apparatus of the woodpeckers is specially modified; the basihyal is very long and slender, bearing stunted cerato- and glossohyals at its extreme end; there is no urohyal, or only

hyoid, but it is said of the several different elements of which the hyoid bone, or hyoidean arch, is composed, the termination *-al* being conformable with *branchi-al*, etc.

a rudiment; the ceratobranchials are long, and the epibranchials so extraordinarily elongated in some species as to curl up over the back of the skull and forward along the top of the skull to a variable distance; sometimes, as in Fig. 73, curling around the orbit of the eye, or, as in Fig. 74, running into the nostril to the tip of the beak. In such cases they bundle together in passing forward over the skull, and go obliquely to one side.

Other Bones of the Skull.—The articulation of the lower jaw with the quadrate may have certain *sesamoids.* Thus, there are two such *sclerosteous* or ligament-bones in the external lateral ligament of the raven's jaw-joint, and the long occipital style of the cormorant and snake-bird is of the same character, being an ossification in the nuchal ligament of the neck. The siphon-like tube which conveys air from the outer ear-passage to the hollow of the mandible may ossify, as it does in an old raven, for example, resulting in a neat tubular "air-bone" or *atmosteon* (Gr. ἄτμος, air).

Types of Palatal Structure.—The arrangement of the bones of the palate in birds results in several types of structure, first defined by Huxley and applied to the classification of birds. These are the *dromæognathous, schizognathous, desmognathous,* and *ægithognathous;* to which Parker has added the *saurognathous.* Huxley proposed to make the primary division of Carinate birds upon this score; and since the plan could not be made to work in his hands, it is certainly futile for any one else to demonstrate again the impossibility of establishing the higher groups of birds upon any one set of characters,—upon the modifications of any one structure. Nevertheless, when duly co-ordinated with other characters, palatal structure becomes of the utmost importance in defining large groups of birds. It is necessary, therefore, for the student to clearly understand this matter, which I will lay before him as nearly as possible in the words of the authors just mentioned.

Dromæognathism (Gr. δρομαῖος, *dromaios,* a runner: genus-name of the *emeu*). All the Ratite birds, and the tinamous alone of Carinate birds, are *dromæognathous.* "The posterior ends of the palatines and the anterior ends of the pterygoids are very imperfectly, or not at all, articulated with the basisphenoidal rostrum, being usually separated from it, and supported by the broad, cleft, hinder end of the vomer. Strong basipterygoid processes, arising from the body of the basisphenoid, and not from the rostrum, articulate with facets which are situated nearer the posterior than the anterior ends of the inner edges of the pterygoid bones." This is the gist of *dromæognathism;* it is exhibited in several ways. (*a*) In *Struthio* alone, Fig. 75, the very short vomer, borne upon the rostrum, articulates neither with palatines nor with pterygoids, but with the maxillo-palatines; and the palatines, which are remote from the rostrum,

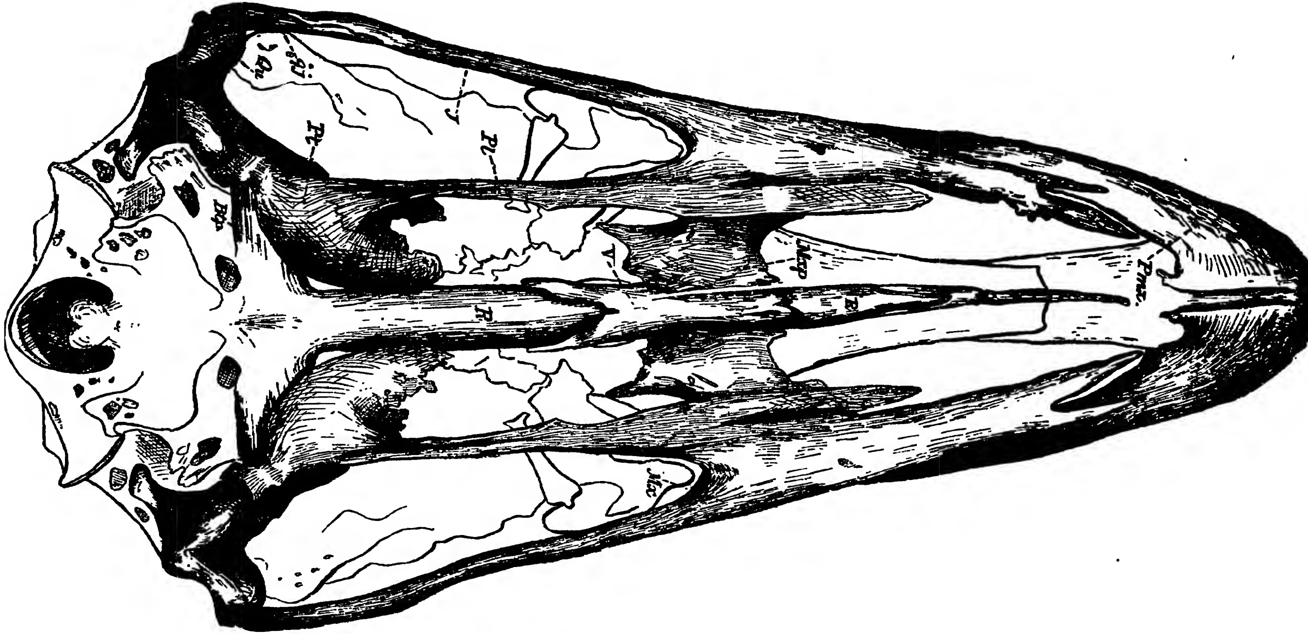


FIG. 75.—*Dromæognathous* skull of Ostrich, 7-8 nat. size, from specimen No. 16,629, United States National Museum, by Dr. R. W. Shufeldt, U.S.A. *RR*, rostrum, beyond which the ossified nasal septum continues in the axis of the skull to the letters "*Pmx.*" *V*, the short vomer, borne upon *R*, uniting laterally with *Mxp*, the broad maxillopalatines; *Pl.* palatines, remote from rostrum, underrunning beyond *Mxp*, but not to *Pmx.* *Pt*, expanded scroll-like pterygoids, articulating behind with *Btp*, the strong basipterygoid processes on the body (not rostrum) of the sphenoid; they underlap *R*, but do not articulate there. *Pmx*, premaxillaries; *Mx*, maxillaries, whose ends run forward to opposite the letters "*Pmx*"; *j*, jugal; *qj*, quadratojugal; *Qu*, quadrate. (N.B.—This is the most exceptional case of dromæognathism. Each one of the Ratite families,—*Struthionidæ*, *Rheidæ*, *Casuariidæ*, *Dinornithidæ*, and *Apterygidæ*,—as well as the Carinate family *Tinamidæ*, offers a special case of such formation, as explained in the text.)

advance beyond the maxillopalatines, as in most birds. (*b*) In *Rhea*, the vomer is as long as usual in birds, and articulates behind with the palatines and pterygoids, but does not join the maxillopalatines in front; the short palatines unite with the inner and posterior edges of the thin fenestrated maxillopalatines. (*c*) In *Casuarius* and *Dromæus* (cassowary and emeu) the long vomer articulates behind with the palatines and pterygoids, and unites in front with the maxillopalatines; these are flat, imperforate, and solidly joined to the premaxillæ; the palatines are short. (*d*) The extinct *Dinornis*

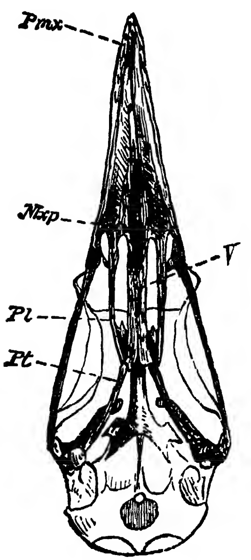


FIG. 76. — *Dromæognathous* skull of tinamou (*Tinamus robustus*); copied by Shufeldt from Huxley. Letters as before.

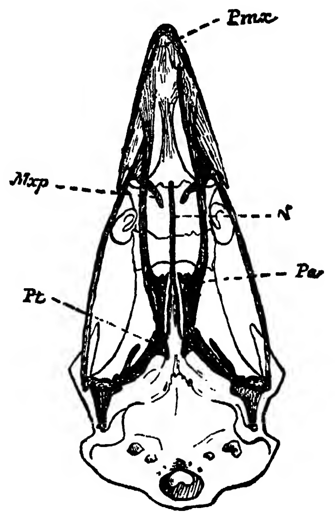


FIG. 77.—*Schizognathous* skull of common fowl, nat. size; from nature by Dr. R. W. Shufeldt, U.S.A. Letters as before, except *Pa*, palatine.

had flat imperforate maxillopalatine plates uniting solidly with the premaxillæ, and probably with the vomer, as in *Dromæus*. (*e*) In *Apteryx* the long vomer unites with palatines and pterygoids behind; short broad palatines suture obliquely with flat imperforate maxillopalatine plates, which unite both with premaxillary and vomer. (*f*) The tinamous, *Dromæognathæ* (Fig. 76) "have a completely struthious palate"; vomer very broad, uniting in front with broad maxillopalatine plates as in *Dromæus;* behind articulating with posterior ends of palatines and anterior ends of pterygoids, both of which are thus prevented, as in all *Ratitæ*, from any extensive connection with the rostrum; basipterygoid processes springing from body of

sphenoid, not from its rostrum, articulating with pterygoids very near the posterior or outer ends of the latter; and head of quadrate with a single articular facet, as in *Ratitæ*.

Schizognathism (Gr. σχίζω, *schizo*, I cleave) is the kind of "cleft palate" shown by the columbine and gallinaceous birds, by the waders at large, and many of the swimmers (see Fig. 77). In this general case, the vomer, whether large or small, tapers to a point in front, while behind it embraces the basisphenoidal rostrum, between the palatines; these bones and the pterygoids are directly articulated with one another and with the basisphenoidal rostrum, not being borne upon the divergent posterior ends of the vomer; the maxillopalatines, usually elongated and lamellar, pass inwards over [*under*, when the skull is viewed upside-down, as it usually is] the anterior part of the palatines, with which they unite and then bend backwards, along the inner edge of the palatines, leaving a broader or narrower fissure between themselves and the vomer, on each side, and do not unite with one another or with the vomer. It follows from this that in the dry skull of a plover, for instance, which shows the schizognathous arrangement extremely well, "the blade of a thin knife can be passed, without meeting with any bony obstacle, from the posterior nares alongside the vomer to the end of the beak." There are several groups of birds which exhibit the schizognathous plan, with ulterior modifications of palatal and other characters. (*a*) The columbine birds (*Peristeromorphæ* of Huxley's arrangement): maxillopalatines elongate and spongy; basipterygoid processes narrow, but prominent. (*b*) The gallinaceous birds (*Alectoromorphæ*): maxillopalatines varying greatly in size, but always lamellar: palatines long and narrow, with rounded-off postero-external angles; basipterygoid processes oval, flattened, sessile upon the rostrum, articulating with the pterygoids. (*c*) The penguins (*Spheniscomorphæ*): maxillopalatines concavo-convex and lamellar; no basipterygoid processes; pterygoids flattened. (*d*) In the gulls, petrels, loons, grebes, and auks, constituting the *Cecomorphæ*, the maxillopalatines are usually lamellar and concavo-convex, but may be spongy, tumid, and closely approximated to the vomer; and basipterygoid processes are absent or present. (*e*) In the cranes, rails, and their allies (*Geranomorphæ*), the maxillopalatines are concavo-convex and lamellar, and basipterygoid processes are usually absent. (*f*) In the plover-snipe group, or limicoline *Grallæ* (*Charadriomorphæ*), the maxillopalatines are always concavo-convex and lamellar; the basipterygoid processes narrow and prominent. Excepting perhaps group *d*, which does not hang together so well, the schizognathous groups here noted correspond very closely with recognised orders or suborders of birds; in all of them, the maxillo-palatines are perfectly distinct from one another and from the vomer,

and the latter is slender and usually pointed. There are plenty of other birds in which the former factor in the case obtains; but in these the vomer is broad and usually truncate in front (see *Ægithognathism*, beyond).

Desmognathism (Gr. δεσμός, *desmos*, a bond) is exhibited in one or another style by those swimming and wading birds which are not schizognathous, by the birds of prey, and various non-passerine perching birds. It does not fadge so well as any other one of the palatal types of structure with recognised groups of birds based on other considerations. In this "bound-palate" type the vomer is either abortive or so small that it disappears; when existing it is usually slender and tapers to a point in front; the maxillopalatines are united across the median line, either directly or by means of ossifications in the nasal septum; the posterior ends of the palatines and the anterior ends of the pterygoids articulate directly with the rostrum (as in schizognathism). This type is simply and perfectly exhibited by a duck (Fig. 78) in which the maxillopalatine is a broad flat plate united with its fellow in mid-line; the oval sessile basipterygoid facets are far forward, opposite the very ends of the pterygoids. In the flamingo, ibis, spoon-bill, stork, heron, the united maxillopalatines are tumid and spongy, filling the base of the beak; basipterygoids are wanting (rudimentary in the flamingo). In totipalmate swimmers (pelican, cormorant), desmognathism is carried to an extreme by union of the palate bones also across the mid-line; the general arrangement is as before. The birds of prey exhibit

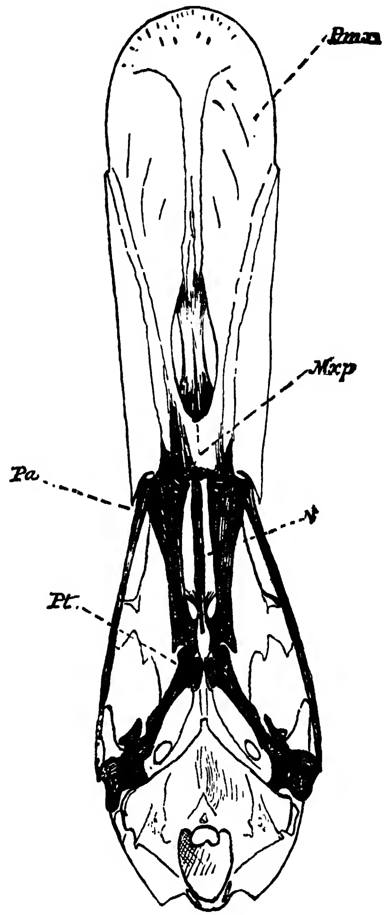


FIG. 78.—*Desmognathous* skull of mallard duck, *Anas boscas*, nat. size; from nature by Dr. R. W. Shufeldt, U.S.A. Letters as before.

several special conditions of desmognathism. The parrots are another case; among other cranial characters of these birds is to be noted the *articulation* of the palate bones with the upper beak, like that of the zygoma. The multifarious Picarian birds, or non-passerine Insessores, are desmognathous, excepting the schizognathous trogons (*Trogonidæ*) and the "saurognathous" woodpeckers. Parker has described the following categories of desmognathism: (*a*) *Perfect direct*, the maxillopalatines uniting below at the midline; either with the nasal septum free from such bony bridge, as in a duck; or ankylosed therewith, as in many birds of prey. (*b*) *Perfect indirect*, very common, as in eagles, vultures, owls; maxillopalatines separated from each other by a chink, but ankylosed with nasal septum. (*c*) *Imperfectly direct;* maxillopalatines sutured together but not ankylosed. "In young falcons and hawks the palate is at first indirect, is then imperfectly direct, and at last perfectly direct." (*d*) *Imperfectly indirect;* maxillopalatines closely articulated with, and separated by, the "median septomaxillary"; but there is no ankylosis. (*e*) *Double:* the palatines united as well as the maxillopalatines; as in the pelican and cormorant above noted, in certain Caprimulgine birds, horn-bills, etc. (*f*) *Compound:* when the properly *ægithognathous* skull of a passerine bird becomes also desmognathous.

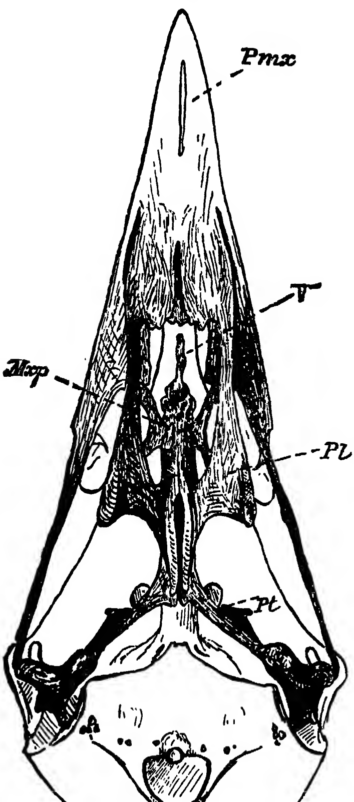


FIG. 79.—*Ægithognathous* skull of raven, *Corvus corax*, nat. size; from nature by Dr. R. W. Shufeldt, U.S.A. Letters as before. N.B. The misplaced reference line, *V*, goes to the ossified nasal septum borne upon the end of the vomer, which latter bone begins at the thickest part of the central projection. *Mxp* underlies *V* and overlies *Pl*, but touches neither.

Ægithognathism (Gr. αἰγιθαλός, *aigithalos*, some small bird) is exhibited almost unexceptionally by the great group of Passerine birds; it is also nearly coincident with *Passeres*, though a few other birds, notably the swifts (*Cypselidæ*), also exhibit it. Huxley's term

Coracomorphæ, nearly synonymous with *Passeres*, relates to the palatal structure exhibited by a raven (Fig. 79), as typical of that of *Passeres* at large. The vomer is a broad bone, truncate in front and deeply cleft behind, embracing the sphenoidal rostrum in its forks. The palatines have produced postero-external angles. The maxillopalatines are slender at their origin, extending inward and backward over the palatines and under the vomer, where they end free, being united neither with each other nor with the vomer. This disconnection of the maxillopalatines is *quoad hoc* "schizognathous," of course; but such condition, in *association with* the peculiarities of the vomer, is ægithognathous. The nasal septum in front of the vomer is often ossified in ægithognathism, and the interval between it and the premaxillæ filled up with spongy bone; but no union takes place between this ossification and the vomer (Huxley). According to Parker, the distinguishing character of the ægithognathous type is the union of the vomer with the alinasal wall and turbinals. He distinguishes four styles: (*a*) *Incomplete*; very curiously exhibited by the low *Turnix*, which stands near the gallinaceous birds. (*b*, *c*) *Complete*, as represented under two varieties, one typified by the crow, an Oscine Passerine, the other by the Clamatorial Passerines *Pachyrhamphus* and *Pipra*. (*d*) *Compound*, *i.e.* mixed with a kind of desmognathism, as noted above. "Vomer truncated in front" is the general expression for the condition of that bone in the ægithognathous type; it is frequently massive in that direction, and of endlessly varied configuration.

Saurognathism (Gr. σαῦρος, *sauros*, a lizard; Fig. 80). According to Huxley the woodpeckers exhibit a "degradation and simplification of the ægithognathous structure." The peculiarities of the palate of these birds (including *Picidæ*, *Picumnidæ*, and *Iyngidæ*) are so decided that Parker proposes to call them *saurognathous*. The structure is very difficult to make out, and may be understood best by study of the accompanying figure, copied from Parker. The maxillopalatines, *mxp*, are very slight, not extending inward beyond the outer margin of the palatines, and being sometimes quite rudimentary. In front of them, an additional little palatal plate of the maxillary, *pmx*, is developed. The vomers, *v*, are delicate paired rods on each *side* of the median line. The postero-external angle of the palatine is either rounded off or obtuse-angled. Where the broad main part of the palatine suddenly narrows is developed an interpalatine process, *ipa*. The ethmopalatine plates, *epa*, or internal superior plates of the palatine, which are of variable length, are connected by the most marked *mediopalatine* ossification, *mpa*, seen in the class of birds. Bridges of bone are deposited along the inner borders of the palatines; such are the septomaxillaries, *smx*, and other formations which, like the mediopalatine, serve to bind the

palate halves together. The nasal chambers are unusually simple; there are peculiarities of the tympanic cavity and quadrate bone.

"All these things being considered," says Parker, in conclusion, "it will seem contradictory now to assert the great uniformity of the skulls of Birds, and indeed of Birds themselves. Yet so it is, and the countless modifications that offer themselves for observation are gentle in the extreme. One form is often seen to pass into another by almost insensible gradations. . . . In the rest of the Birds' organisation abundant evidence of the same specialisation will be seen. The mind fails to desire more beauty or to contemplate more exquisite adaptations. An almost infinite variety of Vertebrate life is to be found in this class. Of its members some dig and bury their germs, which rise again in full plumage, whilst others watch and incessantly feed their tender brood in the shady covert or 'on the crags of the rock and the strong place.' In locomotion some walk, others run, or they may wade, swim, plunge, or dive, whilst most of them 'fly in the open firmament of heaven.'" (*Ency. Brit.* 9th ed. Art. "Birds," p. 717.)

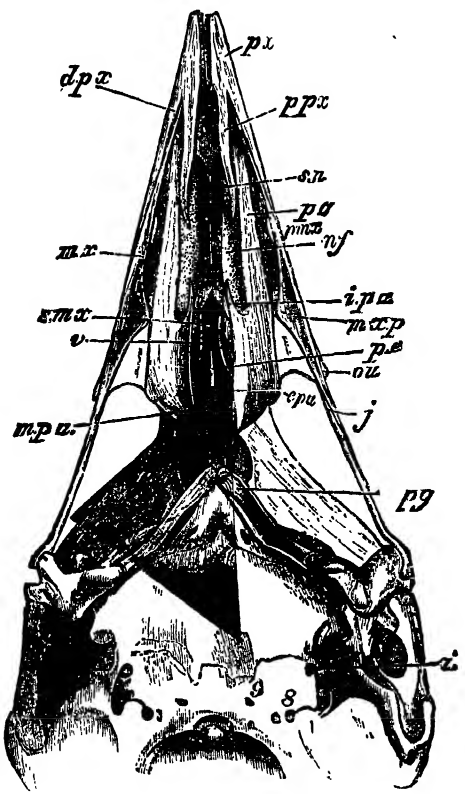


FIG. 80.—*Saurognathous* skull of nestling *Picus minor*, ×4 diameters, after Parker. *Px*, premaxillary; *dpx*, its dentary process; *ppx*, its palatal process; *sn*, septonasal; *pa*, palatine; *pmx*, peculiar palatal plate of maxillary of a woodpecker; *nf*, nasal turbinal; *mx*, maxillary; *ipa*, interpalatal spur of palatine bone; *mxp*, rudimentary maxillopalatine, scarcely reaching palatine; *smx*, septomaxillary, in several pieces; *v*, right vomer, its fellow opposite; *pe*, lower border of perpendicular plate of ethmoid, between vomers; *epa*, ethmoidal (inner) plate of palatine; *mpa*, mediopalatine; *pg*, pterygoid; *i*, foramen for internal carotid; 8, for vagus nerve; 9, for hypoglossal nerve.

b. Neurology; The Nervous System; Organs of Special Senses

The Nervous System of any Vertebrate determines the form of such an animal; in fact, the beautiful skeleton we have examined is simply a sketch in bone of the *cerebrospinal nervous system*, conformably with which the whole bony framework of the body is erected. A brain and spinal cord and their lateral prolongations or nerves are the commanding superadditions, in a vertebrate, to any such nervous system as an invertebrate may or does possess. Besides the vertebral or main nervous system, all brainy vertebrates retain a *sympathetic system* of nerves, supposed to represent a modified inheritance of the corresponding nervous system of Invertebrates. Thus the cerebrospinal and sympathetic are the two distinct nervous systems of all vertebrates which have a skull and brain. The former presides over the *animal* life of the creature,—its sensations, perceptions, and voluntary actions; the latter more especially over its *vegetative* functions, as digestion, respiration, circulation, and reproduction, which are more or less involuntary. But the two are inseparably connected, anatomically and physiologically, so that no distinct line can be drawn between them. Nerve-tissue consists of an aggregation of nerve-cells and their investing substance,—the bodies of a myriad *Neuramœbæ* agglutinated by their secretions. They are of two species: *Neuramœba cinerea* and *N. candida.* The former are usually multiradiate, inosculating cells of nerve-substance, which form the "gray matter" of the brain and spinal cord and the *ganglia* (knots) of nerves; the latter are white, thready, and form the connections of the ganglionic masses and the whole substance of ordinary nerve-cords. The gray amœbas are the immediate communicants between the mind and the body of the creature; the white amœbas are the mediators between the body and outward things. The gray amœbas translate thought in terms of matter, and conversely; the white convey the translation. How this is done, no one knows, but the fact is manifest. In ordinary language, gray nerve centres receive from white tracts impressions made upon the periphery of the nervous system; and, with or without the knowledge and consent of the animal, convert these impressions into appropriately responsive actions. This is called the "reflex action" of the nervous system. Some think such reflection is the principal or only activity of the nerve-tissue, taking animals to be mere automata, the mechanism of which is only set in motion by external stimulation. Others think that animals, and even human beings, have in their consciousness an inner spring of action, vaguely called "spiritual," whose operations upon the matter of their bodies

manifests what is called by some "mind," by others "soul." I am satisfied of the correctness, in the main, of the latter view; but, however this may be, it is quite certain that white nerve-tissue is a means of carrying something to and fro, which something is called a "nerve impulse," for want of knowing what it is. White nerves have therefore an *efferent* function, when they carry impulses outward from gray centres, and an *afferent* function, when they bring impulses into gray centres. The former is their *motor* function; the latter is their *sensory* function. In nerves at large, impulses of both kinds travel in the same tracts without interference; such mixed nerves are therefore called *sensorimotor*. Thus, each spinal nerve has a posterior sensory ganglionated root, and an anterior motor simple root, which soon blend in one cord, in which both functions coexist. Some nerves seem to be entirely motor, as those which move muscles of the face and tongue. The purest sensory nerves are those of "special sense," as the olfactory, optic, and auditory. Some nerves are so "mixed" as to combine functions of special sense, common sensation, and motion, as that called glossopharyngeal, which moves, feels, and tastes. The motor effluence of nerve-tissue upon itself and other parts of the body is literally *animation*; the sensory influence is nominally *materialisation*. The physical mechanism of these occult processes in a bird is as follows:—

The Brain (Lat. *cerebrum*; Gr. ἐγκέφαλον, *egkephalon*, the encephalon) is the anterior dilatation and complication of the main nervous axis of the body, contained within the skull. It resembles a soap-bubble blown at the end of a pipe, being not less beautiful in its iris-quality, and not less lasting. It is primarily triune, or threefold, beginning as three such bubbles, called the *anterior*, *middle*, and *posterior cerebral vesicles*, corresponding to what are afterward the fore-brain, mid-brain, and hind-brain, or *prosencephalon*, *mesencephalon*, and *opisthencephalon*. Two of these primitive vesicles subdivide each into two, so that five segments of the brain result. These five are commonly called *prosencephalon*, *diencephalon*, *mesencephalon*, *epencephalon*, and *metencephalon*, named from before backward; and they respectively correspond with parts of the adult brain known as cerebrum proper, optic thalami, optic lobes, cerebellum, and medulla oblongata. The birth and multiplication of gray neuramœbas cause thickenings of the bladdery membranes in various places and ways; all such gray deposits are the *ganglia* of the brain, and the great peripheral ganglion is the *cortical* layer or "bark of the brain." Similar deposits of white neuramœbas connect all these ganglionic colonies, furnishing various *commissures* of the brain. The cavity of the original bubbles, continuous with the hollow of the pipe-stem or spinal cord (which was at the outset a furrow along the back of the embryo, not a tube) becomes partially divided up into several

communicating hollows; these are the *ventricles* (little bellies) of the brain. Actual prolongations of brain-tissue, or nervous threads like the ordinary spinal nerves, pass out of the brain-box; these are *cerebral nerves,* oftener called *cranial nerves;* there are twelve pairs of them. At the pituitary space, just behind which the notochord ends (see Fig. 64), is developed a remarkable structure, the *pituitary body:* its nature is unknown. This lies under the brain; opposite it, on top of the brain, is another curiosity, the *conarium* or *pineal body;* it has been considered the special seat of the soul by some, though others have located that throne of animal grace in the solar plexus of the sympathetic system, which is in the belly. It is probably the remains of an extinct eye. The pituitary and pineal are also called respectively the *hypophysis* and *epiphysis cerebri.* They lie respectively at the bottom and top of one of the cavities of the brain, arbitrarily called the *third ventricle;* the anterior wall of this ventricle is the *lamina terminalis,* or terminal sheet of the brain, with which, morphologically speaking, the brain ends in front; though, in its actual growth, the prosencephalon crowds ahead of this formation. As the brain-cells multiply, the prosencephalon outgrows the associated parts, and becomes nearly separated into lateral halves; these are the *hemispheres of the cerebrum,* or "halves of the great brain"; they retain their ventricles, which intercommunicate through a passage-way, which also leads into the third ventricle; this is the *foramen of Monro.* Each sends out in front a hollow process; these processes are the *olfactory lobes,* or *rhinencephalon* ("nose-brain"). A great ganglionic thickening of gray matter in the interior of each hemisphere is the *corpus striatum;* these "striped bodies" are connected by the *anterior commissure* of the brain. The rest and greater part of the original anterior cerebral vesicle makes up by ganglionic thickening of its sides into what are called misleadingly the *optic thalami,* since these tracts have nothing to do with the sense of sight. The thalami and associate parts behind the lamina terminalis (third ventricle, etc.) compose what some call the *thalamencephalon,* or "bed-brain," others the *diencephalon,* or "'tween-brain." The original middle cerebral vesicle makes up underneath into longitudinal commissural fibres, called the *crura cerebri,* or "legs of the brain," connecting fore and aft parts; but especially composes the ganglionic centres called *corpora bigemina,* or "twin bodies." These are the *optic lobes,* or "eye-brain." They are connected by transverse commissure. The optic ganglia and commissure, the cerebral crura, and contained cavities, essentially compose the *mesencephalon,* or "mid-brain." The original posterior cerebral vesicle (opisthencephalon) becomes separated into two parts: the fore part of it is moulded into the considerable mass of the *cerebellum* ("little brain"); which, with its connections of

white substance (pons Varolii, peduncles, etc.) and the hollow underneath it ("fourth ventricle") constitutes the epencephalon of most writers, by some called the *metencephalon*, or "after-brain." The hind part of it tapers off into the spinal cord; this tapering part is the *medulla oblongata*, or "oblong marrow," also called the *myelencephalon*, or "marrow-brain" (and by some the *metencephalon*). This description is pertinent to brains at large, representing the general plan of structure; any fairly developed encephalon shows the parts specified; and the most complicated brain, that of man, only shows what elaborate finishing touches may be given to the simple structure thus outlined, when cells, both white and gray, but especially the latter, are profusely furnished, to the ornamentation of the mind's estate with race-tracks great and small, and the place of fornication,—fruits of the olive, and of the arbor vitæ. The membranes, or *meninges*, which hide all this from the uninitiated, are three. The *pia mater*, or "tender mother," which immediately invests the brain, is very vascular, and furnishes the blood supply; not only by small arteries which immediately penetrate the substance of the brain, but by enfolded sheets which enter the ventricles, and are called *choroid plexus*. The *arachnoid*, or "cobweb," comes next; a serous fluid which it secretes bathes the brain, and meets concussion with its gentler fluctuation. The *dura mater*, or "stern mother," is a dense outer membrane which enwraps and holds the whole firmly. These meninges descend into the spinal column, and answer the same purpose there, maintaining the same disposition around the spinal cord.

The Bird's Brain offers the following comparative characters: It is compact, having nothing of the straggling apart of its elements seen in low vertebrates, and completely fills the cranial cavity. Its long axis is about transverse to the axis of the spinal column. The cerebral hemispheres are well developed, but do not cover the cerebellum or optic lobes; from their dome the rhinencephalon protrudes like a porte-cochère. Their surface is quite smooth (devoid of the gyri and sulci of most mammalian brains); even the Sylvian fissure is barely indicated. The optic lobes are of immense size, relatively to those of higher vertebrates, and relatively to the rest of the encephalon; they appear much loosened from their surroundings, at the *sides* and *lower part* of the mid-brain; they retain their ventricles, as does also the rhinencephalon. The corpora striata are very large. The *fornix* is rudimentary. The cerebellum is well developed and deeply sulcate, with transverse fissures, but is not divided into right and left lobes; a "fleecy" lobule on each side, the *flocculus*, is well defined, and received in a special recess of the inner wall of the skull. Parts of the medulla oblongata notable in mammals are obscure or obsolete. There is no *pons Varolii*, or superficial trans-

verse commissure of the cerebellum, nor any *corpus callosum*—that great white commissure of the cerebral hemispheres which is characteristic of all but the lowest mammals.

The Spinal Cord, or *medulla spinalis* ("spinal marrow") is the main nerve-axis of the body, running in the series of neural arches of the vertebræ from head to tail; it directly continues the medulla oblongata. It retains its primitively tubular character in part at least, and consists as usual of white matter enclosing gray matter. The cord is fissured into lateral columns, as these are also to some extent into anterior and posterior tracts. The latter diverge in ascending the medulla oblongata, to throw the central tube into the cavity of the fourth ventricle; and especially in the sacral region, where a sort of ventricle, known as the avian *sinus rhomboidalis*, is similarly formed. The calibre of the cord increases at the root of the neck, where large nerves are to be given off from the brachial plexus to the wings, and again in the sacral region, with the same reference to nerve-supply of the legs; after which the cord continues to the end of the spinal canal as a terminal thread.

The Cranial Nerves are twelve pairs, as in mammals, the highest vertebrate number. **1**, the *olfactory* nerve of special sense (smell); origin from rhinencephalon; exit from cranial cavity by olfactory foramen, high up in orbital cavity; conducted along a groove to final escape between perpendicular and lateral plates of ethmoid into the nasal chambers; distributed to the investing mucous membrane of the septal and turbinal bones of the nose. The exit is through a sieve-like or *cribriform* plate only in *Apteryx* and *Dinornis* (Owen). **2**, the *optic*, nerve of special sense (sight); origin from optic lobe and thalamus; of great size, and forming a *chiasm* (decussation) with its fellow; exit by optic foramen, a large hole in back of orbital cavity between centres of orbitosphenoid and alisphenoid, close to or in common with its fellow. This nerve forms the retina of the eye. **3**, **4**, **6**, the *oculimotor*, *pathetic*, *abducent*, collectively the motor nerves of the eye, supplying the muscles moving the eyeball; **3**, to all these muscles excepting superior oblique, and external rectus; origin from crura cerebri, base of mesencephalon; **4**, to the superior oblique, origin behind optic lobes, upper surface of metencephalon; **6**, to external rectus (also to muscles of the third eyelid in birds); origin between met- and myel-encephalon, base of brain; **3**, **4**, **6**, exits from cranial into orbital cavity by several small, not constant, foramina near optic foramen; or by this foramen sometimes all the nerves which enter the orbit pass out of brain cavity through one great hole. **5**, great *trifacial* or *trigeminal*, sensorimotor; feeling skin of head, moving muscles of jaws; origin (double) from myelencephalon; leaves brain from sides of metencephalon; sensory root has Gasserian ganglion;

motor root simple. This nerve has three divisions, whence its name; 5a, *ophthalmic* division, the most distinct; exit from cranial into orbital cavity by separate foramen above and to outer side of optic foramen; grooves orbital wall in passing; *ciliary* ganglion; distribution mainly to lacrymal and nasal parts; traceable to end of upper mandible; 5b, *superior maxillary;* exit by foramen ovale, in alisphenoid or between that and proötic centre; distribution to side of upper jaw; *Meckelian* ganglion; 5c, inferior maxillary, derived chiefly from motor root; exit same as 5b; distribution to lower jaw (muscles, substance of bone, integument); no *special sense* (gustatory) function; no *otic* ganglion. 7, *facial* or *portio dura*, motor; origin from myelencephalon; enters periotic bone, escapes from ear behind quadrate bone, by what corresponds to stylomastoid foramen of mammals; communicates with 5c by *chorda tympani* nerve, with 9, 10, 12, and sympathetic system; distribution to skin-muscles and others of lower jaw and tongue, etc. 8, *auditory* or *portio mollis*, nerve of special sense (hearing); origin with 7; no exit from skull; enters meatus auditorius internus of periotic bone; forms auditory apparatus in labyrinth of ear. 9, *glossopharyngeal*, mixed nerve, sensorimotor and gustatory (taste); origin myelencephalon; exit by foramen in exoccipital bone, behind basitemporal, near lower border of tympanic recess; distribution to muscles and membranes of gullet, throat, tongue, etc. 10, *pneumogastric*, sensorimotor; origin and exit next to 9; distribution to windpipe, lungs, gullet, stomach, heart, etc.; has recurrent syringeal to vocal organs. 11, *spinal accessory*, sensorimotor; origin upper part of spinal cord; exit with 9, 10; distribution to these nerves and to muscles of neck. 9, 10, 11, are intimately connected with one another, and with other nerves, especially 10 with sympathetic. The several foramina in a bird's skull, which may be seen in the place indicated at 8, Figs. 69, 70, are for the divisions of this composite *vagus* or "wandering" nerve of respiration, circulation, digestion, etc.; they represent morphologically a *foramen lacerum posterius*, between exoccipital and opisthotic centres. 12, *hypoglossal*, motor nerve of the tongue; origin from myelencephalon; exit by anterior condyloid foramen in front of the occipital condyle. Thus the plan of the cranial nerves of birds is nearly coincident with that of mammals.

The Spinal Nerves, in pairs, correspond in a general way to the vertebræ, between which they pass out by *intervertebral foramina*, to supply the body at large. They are sensorimotor; arise from the spinal cord by anterior motor and posterior sensory (ganglionated) roots which unite before leaving the spinal canal; in the sacral region the main branches leave by separate foramina. They form *plexuses* or interlacements. The principal of these is the *brachial plexus;* constituted by several lower cervical nerves, and

one or two usually counted as dorsal, which combine to form a single cord, whence the nerves of the wing are derived. Similar network of three to five true sacral nerves furnishes the nerves of the leg.

The Sympathetic System consists of a pair of nervous cords running lengthwise below the bodies of the vertebræ, one on each side in the trunk, and in corresponding relations with cranial bones. An extensive and intricate series of communications is effected with the nerves of the cerebrospinal system, excepting the special-sense nerves of smell, sight, and hearing. The points of communication form a chain of sympathetic ganglia; from these knots, the most conspicuous features of the system, nervous cords pass to their distribution in the motory mechanism of the heart and blood-vessels and other viscera. The anterior sympathetic nerves are the *iridian;* the anterior ganglia are the *sphenopalatine* or *Meckelian*, intimately connected with cranial nerves. The system ends behind in the caudal region of the spine by a *ganglion impar.*

Sense of Smell: Olfaction.—The sense of smell is effected by terminal branches of the olfactory (1st cranial) nerve, ramifying in the mucous (pituitary or Schneiderian) membrane of the nasal cavities. Owing to the comparatively small size and little complexity of the foldings and pleatings of bone or cartilage in the nasal chambers, the sensory surface being correspondingly limited, it is not probable that birds possess this sense in a high degree. Besides the cartilaginous or osseous *septum,* generally more or less complete in birds, there are lateral scrolls and whorls of bone in endless diversity in most birds, which may be ossified, or remain gristly. The general cavity is mostly bounded and enclosed by the bony beak; floored by the anterior part of the hard palate; defended on each side by the descending prong of the nasal bone; in the dry skull, it either seems continuous with the great orbital cavity on each side behind, or is separated therefrom by lateral ethmoid (prefrontal) or lacrymal ossifications, or both. Outwardly the nasal chambers open upon the beak by the external nostrils. These openings are minute or quite obliterated in some *Steganopodes,* as pelicans and cormorants. The nasal cavities always communicate with the back part of the mouth by the *posterior nares* (Lat. *naris,* a nostril); they are generally paired, that is, with a partition between them, sometimes united in one median aperture. The olfactory nerve, which is rather a prolongation of the rhinencephalon itself than an ordinary nerve, escaping from the brain-box by a special foramen, traversing the upper part of the interorbital septum in a groove or canal, enters the nasal cavity by a single orifice (excepting *Apteryx* and *Dinornis*), instead of the numerous apertures in a cribriform plate by which its filaments reach their destination in mam-

mals. The true sensitive membrane, in which the nervous filaments end, is that investing *ethmoidal* (septal and turbinal), not maxillary parts. An associate structure of the olfactory organ is the *nasal gland*, sometimes called the *superorbital* gland, from its position in many birds. Thus it is of great size in a loon, and lodged in a large deep crescentic depression on top of the skull over the orbits (Fig. 63, *w*); these crescents nearly meeting each other in the middle line. In other birds it is smaller, and within the cavity of the orbit, but never in that of the nose itself, its secretion being poured into the nasal chamber by a special duct.

Sense of Sight: Vision.—The eye is an exquisitely perfect optical instrument, like an automatic camera obscura which adjusts its own focus, photographs a picture upon its sensitised retinal plate, and telegraphs the molecular movements of the nervous sheet to the optic "twins" of the brain, where the result is "biogenised"; that is, translated from the physical terms of motion in matter to the mental terms of consciousness. But no part of the nervous tract, from the surface of the retina to the optic centre, sees or knows anything about it, being simply the apparatus through which the Bird looks, sees, and knows. In this class of Vertebrates, the optic organs, both cerebral and ocular, are of great size, power, and effect; their vision far transcends that of man, unaided by artificial instruments, in scope and delicacy. The faculty of *accommodation*, that is, of adjusting the focus of vision, is developed to a marvellous degree; rapid, almost instantaneous, changes of the visual angle being required for distinct perception of objects that must rush into the focal field with the velocity at least of the bird's flight. Birds are therefore far-sighted or near-sighted (presbyopic or myopic) according to the degree of *tension* the nerve-tide excites in the eye by the mechanism described farther on; and the transition from one to the other state is effected with great quickness and correctness. Observe an eagle soaring aloft until he seems to us but a speck in the blue expanse. He is far-sighted; and scanning the earth below, descries an object much smaller than himself, which would be invisible to us at that distance. He prepares to pounce upon his quarry; in the moment required for the deadly plunge he becomes near-sighted, seizes his victim with unerring aim, and sees well how to complete the bloody work begun. A humming-bird darts so quickly that our eyes cannot follow him, yet instantaneously settles as light as a feather upon a tiny twig. How far off it was when first perceived we do not know; but in the intervening fraction of a second the twig has rushed into the focus of distinct vision, from many yards away. A woodcock tears through the thickest cover as if it were clear space, avoiding every obstacle. The only things to the accurate perception of which birds' eyes

appear not to have accommodated themselves are telegraph-wires and lighthouses; thousands of birds are annually hurled against these objects to their destruction.

The *orbital cavity*, *orbit*, or socket of the eye, has been almost sufficiently described (see also any Figs. of skull in profile) as that great recess in the side of the skull which is bounded above by the roofing frontal bone, behind by this and sphenoidal elements, in front, if at all, by lateral ethmoidal elements (prefrontal), and separated from its fellow more or less completely by the interorbital septum, which is chiefly the perpendicular plate of the mesethmoid, but may be also in part orbitosphenoidal and presphenoidal. The brim is completed in few birds, by union of lacrymal and postfrontal; in quite a number of birds, however, it is nearly perfected by the approximation of these same bones, as in Fig. 63, *u* and *m*, and in some the rim is carried out by extra supraorbital and infraorbital ossification. There is no bony floor, or only such slight scaffolding as the expansion of the palatine and pterygoid may afford. The zygoma itself, in many dry skulls, seems like the threshold of the orbital chamber. The bony walls may be also defective in some places by great vacuities in the interorbital septum (Fig. 70, *iof*, and Fig. 63, *z*), and others in the cerebral wall, aside from the regular foramina which the nerves pass through. The 1st—6th nerves (p. 261) inclusive usually enter the orbit: of their foramina, the *optic* (Figs. 66, 68, 70, 71, ², and Fig. 63, *y*) is much the largest and most constant, generally blended with its fellow. Those for nerves 1 and 5 (p. 261) are next most obvious and constant; others are often, and all may be, thrown into one large opening. In such a socket as this the eyeball rests upon a cushion of muscle, fat, gland, and connective tissue; and large as is the chamber, the ball fits and nearly fills it. A bird's eyeball is much larger than the opening of the eyelids (see p. 45, note 3).

As to its development: "the *Eye*," says Huxley, "is formed by the coalescence of two sets of structures, one furnished by an involution of the integument, the other by an outgrowth of the brain. The opening of the tegumentary depression, which is primarily [in the very early embryo] formed on each side of the head in the ocular region, becomes closed, and a shut sac is the result. The outer wall of this sac becomes the transparent *cornea* of the eye; the epidermis of its floor thickens, and is metamorphosed into the *crystalline lens*; the cavity fills with the *aqueous humour*. A vascular and muscular ingrowth taking place round the circumference of the sac, and dividing its cavity into two segments, gives rise to the *iris*. The integument around the cornea, growing out into a fold above and below, results in the formation of the eyelids, and the segregation of the integument which they enclose, as the soft and vascular

conjunctiva. The pouch of the conjunctiva very generally communicates, by the *lacrymal duct*, with the cavity of the nose. It may be raised, on its inner side, into a broad fold, the *nictitating membrane*, moved by a proper muscle or muscles. Special glands—the *lacrymal* externally, and the *Harderian* on the inner side of the eyeball—may be developed in connection with, and pour their secretion on to, the conjunctival mucous membrane. The posterior chamber of the eye has a totally distinct origin. Very early that part of the anterior cerebral vesicle, which eventually becomes the vesicle of the third ventricle, throws out a diverticulum, broad at its outer, narrow at its inner end, which applies itself to the base of the tegumentary sac. The posterior, or outer, wall of the diverticulum then becomes, as it were, thrust in, and forced towards the opposite wall by an ingrowth of the adjacent connective tissue; so that the primitive cavity of the diverticulum, which, of course, communicates freely with that of the anterior cerebral vesicle, is obliterated. The broad end of the diverticulum acquiring a spheroidal shape, while its pedicle narrows and elongates, the latter becomes the optic nerve, while the former, surrounding itself with a strong fibrous *sclerotic* coat, remains as the posterior chamber of the eye. The double envelope, resulting from the folding of the wall of the cerebral optic vesicle upon itself, gives rise to the *retina* and the *choroid* coat, the plug or ingrowth of connective tissue gelatinises and passes into the *vitreous humour*, the cleft by which it entered becoming obliterated." (*Anat. Vert.*, 1871, p. 79.)

Birds alone, of all animate beings, may be truly said to "fall asleep" in death. When the "silver cord" of a bird's life is loosed, the "windows of the soul" are gently closed by unseen hands, that the mysterious rites of divorce of spirit from matter may not be profaned. When man or any mammal expires, the eyes remain wide open and their stony stare is the sign of dissolution. Only birds close their eyes in dying. At the same moment, the eye sinks and seems to collapse, by the ebbing of its waters. The closure is chiefly effected by the uprising of the lower lid. These are the principal external differences between the eyes of birds and mammals. The movements of the upper lid in most birds are much more restricted than those of the lower. The few exceptions are chiefly furnished by night birds, as owls, whip-poor-wills, and others of their respective tribes. The lids consist externally of common skin, internally of a layer of *conjunctival* (joining) mucous membrane, with interposed connective tissue: the lower is also stiffened with a smooth plate, the *tarsal cartilage.* The upper is raised by a small muscle, called from its office *levator palpebræ superioris*, arising from the bony orbit. There is no special lowering nor lifting muscle of the under lid; the lids close together by the action of the *orbicularis*

oculi, which nearly surrounds the eye, and whose chief office is to lift the lower lid; the latter has a small distinct *depressor* muscle. Birds have no true hairs, but in some kinds modified filiform feathers answer to eyelashes. When wide open the orifice of the lids is circular, that is, without the inner and outer corners (*canthi*) of almond-eyed creatures like man. There is a *third* inner eyelid, highly developed and of beautiful mechanism: this is the *nictitating* membrane, or "winker" (*nictito*, I wink), a delicate, elastic, translucent, pearly-white fold of the conjunctiva. While the other lids move vertically and have a horizontal commissure, the winker sweeps horizontally or obliquely across the ball, from the side next the beak to the opposite. If we menace a bird's eye with the finger, it is curious to see the winker rush out of the corner to protect the ball. Owls habitually sit in the daytime with this curtain shading the eyes from the glare of light; and doubtless the eagle throws the same screen over its sight when soaring towards the sun. When not in action, the ... lies curled up in ... ..rner of the eye, like those patent window shades which stay up of themselves till pulled down. The ingenious mechanism of the movement of the winker across the lid may be understood with the help of Fig. 81, which represents the *back* of the eyeball. The winker lies in front, on the left hand of the picture, and is to be pulled across the front by the slender tendon, *k*, of the *pyramidalis* muscle, *h*. As *h* contracts it pulls on *k*, and *k*, winding round to the front, pulls the winker to the right hand. But *i* is the optic nerve, entering the ball; *k* would press upon it, were it not fended off by passing, as seen by the dotted line, through a pulley in the end of the *quadratus* muscle, *g*. The harder *h* pulls, the harder does *g* also pull, their consentaneous action at once

FIG. 81.—Right eyeball, seen from behind, showing the muscles: *a*, rectus superior; *b*, rectus externus; *c*, rectus inferior; *d*, rectus internus; *e*, obliquus superior; *f* (not lettered), obliquus inferior; *g*, quadratus; *h*, pyramidalis, with its tendon, *k*, passing through a pulley in the quadratus (as shown by the dotted line) to keep it off the optic nerve, *i*, then passing around the edge of the ball to its insertion in the nictitating membrane.

giving the proper direction to the tendon *k*, and keeping it off the nerve.

Beneath the eyelids, upon the ball, is a delicate filmy membrane not easily recognised on ordinary inspection: this is the *conjunctiva*, so called because it joins the eye to the lids. The *ocular* layer is transparent where it passes over the cornea: it is then reflected away from the ball, to form the *palpebral* layer,—a folding between being the nictitating membrane. The conjunctiva is highly vascular, but the blood-vessels are too small to be seen unless they become congested, when the eye presents the well-known appearance called "blood-shot." Though birds can hardly be said to cry, they have a well-developed apparatus for the manufacture of tears. The lacrymal are two small glands lying one in each corner of the eye, inner and outer. The former, called the *Harderian* gland, is the smaller, deeply seated behind the winker, upon which it pours a glairy fluid: it is an oil-can which not only supplies but applies the fluid to the winker, which needs constant lubricating to work well. The lacrymal gland proper is the outer one, which prepares the tears to moisten and cleanse the conjunctiva; after which they are drained off by the lacrymal duct into the cavity of the nose, which thus becomes a sort of cesspool to receive the refuse waters of the eye. A third gland about the orbit has been already mentioned (p. 264) as pertaining to the nose, not to the eye. Its site is shown in the crescentic superorbital depression, Fig. 63, *w*.

The motions of the eyeball, though more restricted than in mammals, owing to the shape of the ball and its close socketing, are nevertheless subserved by the usual number of *six* muscles. Of these four are called the *recti*, or straight muscles, and two the *obliqui*, or oblique muscles; though they are all "straight" enough, the terms applying to their lines of traction. The four *recti* arise from the bony orbit, near together, about the optic foramen, and pass to be inserted in the eyeball at as many nearly equidistant points on its circumference; the *musculus rectus superior*, Fig. 81, *a*, on top; *m. r. inferior*, *c*, below, antagonising *a*; the *m. r. externus*, *b*, and *internus*, *d*, respectively to the outer and inner (hindward and forward) sides, also antagonising each other. The two oblique muscles arise farther forward in the bony orbit, near each other, and then diverge obliquely upward, *m. o. superior*, *e*, and downward, *m. o. inferior*, *f*, to be inserted near the margin of the globe of the eye, close by the respective insertions of superior and inferior rectus. All the motions of the ball result from consentaneous or dissentaneous action along these six lines of traction; the muscles acting as ropes to pull the ball about, and to steady it in any direction of its axis. The peculiarity of mechanism in a bird is, that the superior oblique goes straight to its insertion, instead of passing

through a pulley which changes its line of traction in mammals. The special nerves presiding over these muscles (3, 4, 6) have been pointed out already (p. 261). In the figure, the cut orbital ends of them all are reflected away from the ball to disclose the underlying muscles of the winker: the reader must mentally bring the six loose ends together and fasten them to the bony orbit at points near about opposite *i*, as above said of their origins.

The above are the principal circumstances and accessories of the optic apparatus; we may now examine the eye itself, of which Fig. 82 gives an enlarged view, in longitudinal vertical section,—the

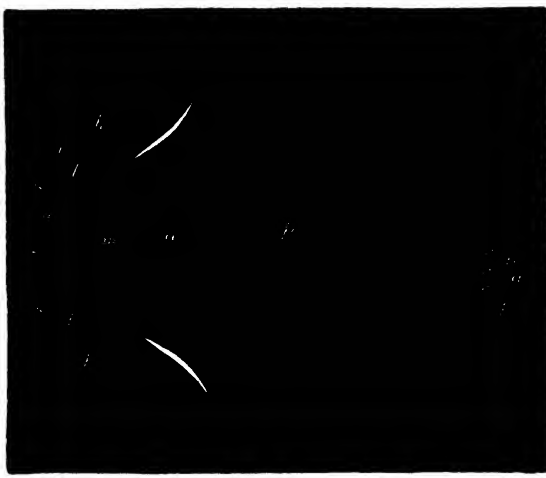


FIG. 82.—Vertical antero-posterior section of eyeball: *a*, optic nerve; *b*, sclerotic, its outer coat; *c*, sclerotic, its middle and inner coats; *d*, choroid; *e*, hyaloid; *f*, marsupium; *g*, cornea; *h*, *h*, bony plates between sclerotic layers; *i*, *i*, corrugations of choroid, forming ciliary processes; *k*, *k*, canal of Petit; *l*, *l*, iris; *m*, anterior chamber of eye; *n*, capsule of the lens; *o*, lens; *p*, posterior chamber of eye. Neither the retina, nor the peculiar sheathing of the optic nerve, is shown. The nerve, marsupium, and ciliary processes, not falling in this section, can only be arbitrarily shown.

nerve, marsupium, and ciliary processes not indeed lying as shown in this section, but so introduced as to display them intelligibly. A bird's eyeball is not nearly so spherical or globular as a mammal's. The globe of the human eye is about a five-sixths segment of a large sphere (sclerotic) with a one-sixth segment of a smaller sphere protruding in front (corneal). The anterior part of the sclerotic of a bird is so prolonged as to be in some cases almost tubular or cylindric, and the corneal protuberance is very convex: the figure may be likened to an acorn which has a short blunt kernel in a heavy shallow cup, or to a thick old-fashioned watch with a very convex crystal. This characteristic shape is fairly shown

in the figure; but some birds' eyes are much more tubular in front,—owls', for example. The eyeball being hollow and filled with fluids which press in all directions, it is hard to see at first how such a peculiar shape is maintained. But the sclerotic coat is very *dense, almost gristly* in some cases; and it is reinforced by a circlet *of bones, the sclerotals, h, h;* see also Fig. 62, where the circlet is *shown. These* are packed alongside each other all around the circumference of one part of the sclerotic, like a set of splints. The large discoidal segment of a bird's eye is mostly composed of the membrane called from its hardness the *sclerotic*,—thick, tough, and strong, of a glistening livid colour. Three sclerotic coats or layers may be demonstrated by careful dissection; in the figure *b* is the outer, *c* the combined middle and inner ones,—much exaggerated as to their distinctness. The bony plates lie between the outer and middle coats anterior to the greatest girth of the eyeball, extending from the rim of the disk nearly or quite to the edge of the cornea. They are a dozen to twenty in number, of oblong squarish shape, tapering toward the cornea, around which they are thus circularly disposed; they are pretty closely bound together, but the circlet as a whole enjoys some little motion back and forward with the varying convexity of the *cornea*, *g*. This last is the thin transparent membrane completing the eyeball in front, like the crystal over the face of a watch. It is very protuberant in birds,—even a hemisphere, or almost tubular. Its structure is not peculiar in birds; but it is remarkable in this class of creatures not only for its convexity, but for the wide range of the variability in convexity which increased or diminished pressure of the contained humours may effect, and its collapse in death.

The sclerotic coat is lined with the *choroid membrane*, *d*, loosely woven of cellular tissue, replete with blood-vessels, and painted pitch-black with a heavy deposit of pigment-cells. It lines the whole globe as far forward as the edge of the sclerotal bones, where it splits in two layers. The *inner* choroid layer turns away from the wall of the eye, toward the interior, and in so reflecting becomes plaited, as a bag is puckered by pulling the strings. These pleats converge upon the rim of the delicate capsule enclosing the lens of the eye, *n*, and there adhere, forming the *ciliary processes*, *i*, *i*. The *outer* layer also starts away from the circumference of the sclerotic wall, as if to pass directly across the cavity, but ends in the *iris*. Around the circumference of the iris, where sclerotic, corneal, and choroid coats come together, is a circular band of fibres, the *ciliary ligament;* and on the outer surface of the choroid is a similar band of circular and radiating contractile fibres, the *ciliary muscle*. These ciliary structures are supposed to be the agents of the accommodating faculty of the eye, acting upon the lens to alter its shape or its

position, or both. This is a difficult matter to settle, when such delicate structures are in question.

The *iris*, *l*, *l*, or rainbow of the eye, is an exquisite structure hanging like a many-coloured curtain vertically between the two compartments of the eye; a highly ornamental framework of the eye's window, being both sash and blind to the pupil. It is suspended vertically in the *aqueous* humour, just in front of the lens. Viewed in front, from the outside, the iris appears as a coloured circular band around the pupil, and seems to come to the surface of the eye. But this is not so, for the conjunctiva, the cornea, and the aqueous humour of the front chamber of the eye, are between us and it. It may be likened to the dial-plate of a watch, which we look at without noticing the interposed crystal. Similarly, the *pupil* of the eye, which shows us our own reflection, diminished to the size of the "eye-baby," may be likened to the round central hole in the dial-plate through which protrudes the shaft that bears the hands of a watch. The "pupil" is the round black spot within the coloured rim of the iris; but it is not a thing—it is a hole in a thing—the hole in the iris through which we may look and see the black choroid coat behind. The quivering iris is very similar in texture to the choroid, being a delicate tissue of interlacing fibres and vessels; but it is highly mobilised by circular and radiating sets of contractile fibres, by which the curtain is tightened and loosened, with corresponding change in the size of the central orifice—the pupil. Although the iridian movements are largely automatic, depending upon the stimulus of light, they are to some extent voluntary, as any one may satisfy himself who observes owls in confinement. During these expansions and contractions of the iris the pupil in birds preserves its circularity; and even when the movement is freest and most voluntary, as in owls, the contracted pupil never appears as a vertical oval figure, or a slit, like that of cats. The round pupil of the great horned owl, *Bubo virginianus*, ranges from the diameter of a finger-ring down to that of a small split-pea. The iridian colours are often striking in birds. Though black and brown are the commonest, yellow is quite frequent, red is often seen, blue and green are rarer; the eyes of cormorants are of the latter colour. The iris is sometimes pure white, as it is in the white-eyed greenlet, *Vireo noveboracensis*. In the Californian woodpecker, *Melanerpes formicivorus*, the eyes are indifferently (or at different ages of the bird, or seasons) brown, bluish, pink, rosy, or yellow.

The *crystalline lens*, *o*, is a transparent biconvex disk like a common magnifying glass, apparently set in the iris like a mirror in its frame, but really hanging a little back of that structure. It is enclosed in a capsular membrane, *n*, of extreme delicacy and trans-

parency, which is in turn set between two layers of the hyaloid membrane to be presently noticed. Where these layers of hyaloid separate around the rim of the capsule to form the investment, a small space is left between them; this circular tube around the lens is the *canal of Petit*, *k*, *k*. The lens is stationed in the axis of vision; some suppose it to be equally stationary in any transverse axis. It is, however, difficult to understand how an object thus suspended in fluctuating humours should be insusceptible of some motion backward or forward as well as of alteration in its degree of convexity; both of which may be factors in the focusing process. From what has preceded, it is evident that the cavity of the eye is divided into anterior and posterior compartments, or chambers, by the reflection, from the sclerotic wall, of the choroid, hyaloid, and iridian structures, which with the lens form a vertical partition. Each chamber is filled with a fluid of different density and consistence. That in the anterior or corneal chamber is thin and watery, and therefore called the *aqueous humour;* that in the sclerotic cavity is more dense and glassy, and for this reason known as the

The *optic nerve*, *a*, of birds is peculiar. In mammals, as a rule, the nerve is a smooth cylinder, proceeding straight to the sclerotic, penetrating the coats of the eyeball directly, near the middle point behind, and then spreading out on the inside of the ball as a large circular concave mirror. This thin, saucer-like expansion of nerve-tissue is the *retina*. In birds the optic nerve is a fluted column, which approaches the eyeball quite obliquely, strikes it at a point eccentric from the axis of the eye, and does not at once pierce the sclerotic. Tapering to a fine point, and running still obliquely, downward and forward, in a deep groove in the sclerotic that would be a tube were it not split, and through a similar slit in the choroid, a fluting of the nerve rises to attain the cavity of the eye, and the retina spreads out from the sides and end of this fold. But the prime peculiarity of a bird's eye is the "purse" or "comb," *marsupium*, *pecten*, *f;* a very vascular structure, like the choroid, and likewise painted black; apparently "erectile," that is, capable of increasing and diminishing in size by influx and efflux of blood. It is attached behind to the nervous structure; is suspended in the vitreous humour, and runs forward obliquely a part or the whole of the way to the lens, to the envelope of which it may be attached in

some cases. Its office is not fully determined. Its great resemblance to the choroid proper suggests a similar function in the absorption of light. If it be turgid and flaccid by turns it must occupy a variable space in the vitreous humour, and in the former state press the waters upon the most yielding part of their walls,—that where the lens is situated, even to the extent of altering the position of the latter; and if so, of changing the focus of the eye. It is difficult to account for the bird's eyes' powers of accommodation by the action of the ciliary muscle in only changing the *shape* of the lens, thus throwing out of account as impossible any change in the position of that refracting medium, or of the density of the refracting humours, or of the convexity of the cornea. The peculiar course of the optic nerve may be simply an anatomical convenience, or may have something to do with a bird's ability to see straight ahead though its eyes be laterally positioned. (See *Am. Nat.* ii. 1868, p. 578; *Pr. Bost. Soc. Nat. Hist.* xii. Apr. 21, 1869.)

Sense of Hearing: Audition.—This is enjoyed to a high degree by the "musical class" of the *Vertebrata*,—birds being the only animals besides man whose emotions are habitually aroused, stimulated, and to some extent controlled, by the appreciation of harmonic vibrations of the atmosphere. Most birds express their sexual passions in song, sometimes of the most ravishing quality to our ears, as that of the nightingale or the bluebird, and it cannot be supposed that they themselves do not experience the effect of music in an eminent degree of pleasurable perturbations. Otherwise they would cease to sing. The capability of musical expression resides chiefly in the more spiritualised male sex; the receptive capacity of musical affections is better developed in the female, who chiefly furnishes the plastic material which is to be moulded into the physical manifestation of the male principle. Quickness of ear is extraordinary in such birds as those of the genus *Mimus*, which correctly render any notes they may chance to hear with greater readiness and accuracy than is usually within human possibility. It may be reasonably doubted that any others than some of the world's greatest musical composers have a higher experience in acoustic possibilities than many birds. Birds' ears have nevertheless a comparatively simple anatomical structure, on the whole much more like that of reptiles than of mammals. Such simplicity is seen in the ligulate or strap-shaped cochlea, the essential organ of hearing, Figs. 84, 85, 86, 87, as compared with the helicoid curvation of the mammalian cochlea. The openness of the ear-parts which lie outside the tympanum is seen in Fig. 62, at the place where the reference-lines "ear-cells" reach the skull; and especially in Fig. 71, where the stapes, *st*, is seen lying in the ear-cavity, the tympanum having been removed.

There is ordinarily no external ear, in the sense of a fleshy conch or auricle, though owls at least have a considerable flap which overlies the auditory aperture. The place of an auricle is filled by a set of peculiarly modified feathers surrounding and overlying the

peels off. Thus this wide shallow depression overlaid with feathers or a slight flap is all there is to represent the "outer ear-passage." The tympanic membrane sometimes develops slight ossification, which then represents the "tympanic bone," or "external auditory process" of human anatomy. Did not this membrane occlude the way, the passage through the ear to the mouth would be pervious. This passage is the modified persistence of the *first visceral cleft* or "gill-slit" of the embryo. Just within the tympanic membrane is the *cavity of the tympanum* or *middle ear*, which may be very extensively exposed by merely removing the membrane. Looking into this cavity, as may readily be done from the outside, in carefully cleaned dry skulls, many objects of interest are presented; among them, a number of foramina—openings leading in various directions. In the first place there are some (inconstant and not readily identified) holes, which are *pneumatic* openings, conveying air from the middle ear-passage to the interior of bones of the skull and lower jaw. Next is observed a large orifice in the lower anterior part of the cavity,—the mouth of the *Eustachian tube*. This tube continues the ear-passage to the mouth, and opens at the back of the hard palate by a median orifice in common with its fellow. In clean skulls of any size a bristle, or even a wooden toothpick, will pass through the Eustachian tube, and appear upon the floor of the skull in mid-line or nearly there, under the basisphenoid, over the basitemporal. The foregoing passages have not conducted us to the

inner ear or proper acoustic cavity. There will be observed, in the side-wall of the tympanic cavity, two definite openings near the Eustachian orifice. One of these, anterior and superior to the other, larger usually, and oval, is the *fenestra ovalis;* it lies in the obliterated suture between the proötic and opisthotic bones; and when the membranous curtain which closes it in life is gone, you look through this "oval window" into the *vestibular cavity* of the ear proper. The lower, posterior, circular orifice is the *fenestra rotunda;* through which round window in the opisthotic bone you look into the *cochlear cavity* of the ear proper. Fenestra ovalis and f. rotunda are generally close together,—only divided by a little bridge of bone, or a mere bony bar. To the circumference of the fenestra ovalis is fitted the expanded oval foot of the trumpet-shaped *columella auris,*—the *stapes,* or "stirrup-bone," as it is called in mammals (Fig. 83, *st*). This is an elegant little bone, which establishes mechanical connection between the membrane closing the fenestra ovalis and the tympanic membrane,—something on the principle of the "sounding-post" inside a violin. It is shown magnified greatly in its embryonic condition in Fig. 67, and there seems to be primitively and morphologically the proximal connection of the *hyoid bone* (by ceratohyal elements) with the bony capsule of the ear; but no trace of this relation persists. Fig. 83 shows the mature stapes of a fowl, and indicates its several elements which have received special names. In skulls prepared with sufficient care, the stapes may be seen *in situ,* as in Fig. 71, *st,*—an extremely delicate rod, stepped into the fenestra ovalis by its foot, the other end protruding freely, and bearing in many cases its hammer-like or claw-like stapedial elements. A stapes I have just picked out of an eagle's ear is a fourth of an inch long, with a stout foot, but a stem as fine as a thread of sewing silk, and at the tympanic end a still finer hair-like process, half as long as the main stem, from which it stands out at a right angle. The ossification is perfect, and there appears to have been another similar process which has broken off from the cross-like figure shown in Fig. 71, *st.* In a raven's skull before me the stapes has fallen into the fenestra ovalis, and lies there with its head sticking out. Though perfectly loose, I cannot withdraw it intact, as the expanded foot fits the hole too closely to pass through in any position I have succeeded in placing it. It appears to be about as large as the eagle's. Close examination at a

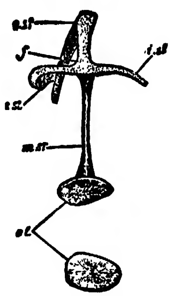


FIG. 83. — Mature stapes of fowl, about × 4; after Parker. *st*, its foot, fitting fenestra ovalis; *mst*, main shaft, or mediostapedial element; *sst*, suprastapedial; *est*, extrastapedial; *ist*, infrastapedial, its end representing a rudimentary stylohyal; *f*, a fenestra in the extrastapedial. (See *st* in situ, Fig. 71, and its embryonic formation, Fig. 67.)

point somewhere about the fenestra ovalis, or between that and the Eustachian orifice, will discover a minute foramen corresponding to the stylomastoid foramen of mammals. It transmits cranial nerve 7 (see p. 262), or the *facial nerve*, which has burrowed through the bony acoustic capsule from the brain-cavity and entered the tympanic cavity on its way to the surface. There are sometimes *two* such minute foramina, close together, both conducting to the brain cavity (neither in common with the internal auditory meatus); as in the eagle, in which large bird a fine bristle just passes through each. Thus in the dry skull of a bird all the hard parts of the middle ear or tympanic cavity, as well as the Eustachian tube, can readily be inspected from the outside; even the limits of the opisthotic and proötic bones can be determined to some extent, and the *ossiculum auditûs* be seen *in situ*. There will also be noted, in most birds, the articular facet upon the proötic bone for the inner head of the quadrate, as well as upon the squamosal for the outer head of the quadrate; however these may shift in position, in different birds, they cannot easily be overlooked or mistaken. Details of mere size and configuration aside, the above general description will apply pretty well to any bird, and should suffice for the identification of the objects seen on looking into the ear, though the number and variety of the irregular *pneumatic* openings may be puzzling at first. To see these things clearly in a *mammal's* ear would require special preparation of the parts, as they lie inside a tympanum which is itself at the bottom of a contracted tube. In such an ear, properly laid open, would be found a chain of *three* ossicles crossing the tympanic cavity from the inner surface of the tympanic membrane to the opposite surface of the membrane closing the fenestra ovalis—the *malleus*, *incus*, and *stapes*, or "hammer," "anvil," and "stirrup"; and the latter would be stirrup-shaped, not trumpet-like with a cross-bar at the mouthpiece. Some mammals would also show a hyoid bone which would have what are the ceratohyals of a bird produced up toward the ear-parts, and continued to these by a bone called *stylohyal*, or "styloid process of the temporal"; and any mammal's jaw would articulate directly with the squamosal,—the chain of three ossicles being entirely inside the ear. As to comparing the parts now: the mammalian stapes is the stapes or columella of a bird,—its stem and foot at least; the incus of a mammal is represented by one of the claws of the cross-bar of a bird's stapes (the *supra*stapedial element; Fig. 83, *sst*); the malleus of a mammal is the great quadrate bone of a bird; the stylohyal of a mammal is not fairly developed in a bird, unless contained in or represented by another claw of the stapes (an *infra*-stapedial element, *ist*); and in these facts is the reason why a bird's lower jaw is articulated indirectly to the skull by means of the

quadrate, and also why a bird's hyoid bone is not articulated or in any way directly connected with the skull—excepting when, as in a woodpecker, elongated *branchial* elements of the hyoid bone take on such office by curling over the cranium (Figs. 73, 74).

Section of the bone is required for further examination of the ear-parts. On longitudinally bisecting the skull, or otherwise gaining access to the brain-cavity, the internal surface of the *periotic* bone is brought into view (Fig. 70, *po*, *op*, *ep*). It is the same bone we have seen in the tympanic cavity, now viewed upon its cerebral surface. In a skull of any size, as that of the eagle before me (from which the rest of my description will be taken), there is no difficulty in making out the parts, although the periphery of the periotic bone is completely consolidated with its surroundings. The periotic or *petrosal* (Lat. *petrosus*, stony—from its hardness), or "petrous part of the temporal," is the bony capsule of the inner ear, enclosing the *labyrinth* or essential organ of hearing,—in fact, it is the skull of the ear, sometimes therefore called the *otocrane*—just as ethmoidal parts form the "skull of the nose," and the sclerotal bones represent a "skull of the eye." The periotic consists of the three bones already often mentioned,—the *proötic*, *po*, *epiotic*, *ep*, and *opisthotic*, *op*, or anterior, superior, and posterior otocranial bones, completely consolidated together, as well as with surrounding bones. The petrosal appears as an irregular protuberance in the inner wall of the brain-cavity, at the lower back part. It seems to be more extensive than it really is, because the great superior semicircular canal, too large to be entirely accommodated in the petrosal, has invaded the occipital bone,—the track of its bed in that bone being sculptured in bas-relief (Fig. 70, *asc*). Behind this semicircular trace, the deep groove of a venous sinus is engraved in the bone, making the tract of the canal still more prominent (Fig. 70, *sc*). The top of the petrosal and contiguous occipital is the floor of a recess or *fossa* in which is lodged the great optic lobe of the brain, partly divided from the general cavity for the cerebral hemisphere by a bony tentorium, like that which in mammals separates the cerebellar from the cerebral fossæ. On the vertical face of the petrosal, or on the corresponding occipital surface, is a large smooth-lipped orifice, at least $\frac{1}{10}$ of an inch in longest diameter; it leads to a tongue-like excavation of the bone, in which the *flocculus* of the cerebellum is lodged. In front, between the petrosal and alisphenoid (or in the conjoined border of one or the other of these bones) is a considerable foramen, conducting the second and third divisions of cranial nerve 5 (see p. 261; Figs. 70, 71, [5]) into the *orbit*. Below the petrosal (in fact, between the opisthotic and the exoccipital), near the border of the foramen magnum, is a foramen (which may be subdivided into foramina), representing the *foramen*

lacerum posterius of mammals, transmitting cranial nerves 9, 10, 11 (see p. 262; Fig. 70, [8]). The general space under description is continued to the margin of the foramen magnum by the exoccipital (Fig. 70, *eo*). Now on the vertical face of the petrosal itself—behind foramen for 5, above that for 9, 10, 11, in front of the large floccular orifice, will be seen a smooth-lipped depression, the *meatus auditorius internus* (Fig. 70, [7]), at the bottom of which are at least *two* separate small foramina. A bristle passed in the upper (or anterior) one of these two holes emerges outside the skull, in the tympanic cavity, near the tympanic end of the Eustachian tube; it has traversed the interior of the petrosal, in a track known as the *Fallopian nerviduct;* it transmits cranial nerve 7—the *facial*, or *portio dura.* A bristle passed into the other of the two foramina may also be made to come out in the tympanic cavity, but by a different track, for it emerges through either the fenestra ovalis or the fenestra rotunda; it has traced the course of cranial nerve 8,—the *auditory nerve*, or *portio mollis.* Both bristles have entered the common internal auditory meatus, but the second one has traversed the ear-cavity proper, through the *labyrinth* of the ear, and come out at the tympanic *vestibular* orifice (fenestra ovalis), or at the tympanic *cochlear* orifice (fenestra rotunda). Either passage is easily made, without breaking down or indeed meeting with any bony obstacle, which would not be the case with a mammal. Cranial nerves 7 and 8 were formerly counted as one (seventh); hence the name *portio dura* "hard portion") for the former, and *portio mollis* ("soft portion") for the latter. The former, as said, traverses the petrosal bone and escapes upon the face; the latter, which is the true acoustic nerve, or nerve of hearing, remains in the bone, being expended upon the labyrinthine structures within—the *vestibule, semicircular canals*, and *cochlea*, which constitute the walls of the cavities in which the essential organ of hearing is snugly encased.

If now, with a very fine saw—the saws now so much used for fancy scroll-work will answer the purpose—the whole periotic mass be cut away from the skull, and then divided in any direction, the labyrinth can be studied. It is best to make the section in some definite plane with reference to the axes of the whole skull,—the vertical longitudinal, or vertical transverse, or horizontal,—as the direction and relations of the contained structures are then more easily made out. Four or five parallel cuts will make as many thin flat slices of bone, affording eight or ten surfaces for examination; the whole course of the labyrinthine cavity can be seen in sections which, when put together in the mind's eye, or held a little apart in their proper relations and visibly threaded with bristles, afford the required picture very nicely. It is extremely difficult to chisel out the affair from the bone in which it is embedded. At first

glance the slices show a bewildering maze,—a continuous network or lattice-work of bone, in which the unaccustomed eye will recognise nothing but confusion. All this *cancellated* structure, however, is pneumatic—the open-work tissue of the bone, containing air derived from the tympanic or Eustachian cavities, and having nothing to do with the ear-passages proper. Parts of the *bony labyrinth* will soon be recognised by their firm smooth walls and definite courses, as distinguished from the irregular interstices of the pneumatic bone-tissue. The bony labyrinth consists of an irregular central cavity, the *vestibule;* of a cavity, projecting like a beak downward and backward from the vestibule, the *cochlea;* and of three horseshoe-shaped tubular cavities, above, behind, and below the vestibule, the *semicircular canals*, the ends of whose hollows all open into the vestibule. Imagine three hollow horse-shoes, with their ends melted into a hollow inflation (vestibule), the opposite wall of which is a hollow projection (cochlea)—or a hollow flat-iron (vestibule) with a long nose (cochlea) and three hollow handles (the canals). Or, see Figs. 84 to 87, representing the contained *membranous* labyrinth, to which the containing bony labyrinth very closely conforms, as it is simply the bony cavity whose walls encase the membranous and other soft structures. According as the sections have been made, numerous cross-cuts of the canals will be seen here and there as circular orifices; the canals themselves lying curled like worms in the petrosal and occipital substance, their ends finally converging to the vestibular cavity. As compared with those of man, the parts are of great size; in the eagle, the whole affair is as large as that part of one's thumb covered by the nail; the whole length of the superior semicircular canal is an inch or more; its calibre, I should judge, being absolutely about as great as in man. The cochlea, however, though not diminutive comparatively, is in a rudimentary condition as far as complexity of structure is concerned, in all *Sauropsida*, representing only the beginning of the cochlear structure of mammals. In the latter class, the cochlea is spirally coiled or whorled on itself like a snail-shell (whence the name—cochlea, a snail), making at least one turn and a half, sometimes five (two and a half in man); with a centre-post or *modiolus* around which winds a bony flange, the *lamina spiralis*, a membranous extension of which to the cochlear out-wall divides the cavity into two compartments or *scalæ* (*scala*, a flight of stairs); it is just like a spiral stairway, only an inclined plane instead of a series of steps. The membranous extension of the bony spiral lamina to the side-wall obviously throws the cavity, as just said, into *two* spirals, which only intercommunicate at the top, where the modiolus ends in a funnel-shaped expansion, the *infundibulum*, beneath the apex of the snail-shell, the *cupola.* A marble rolling down the *upper* stairway would fall into

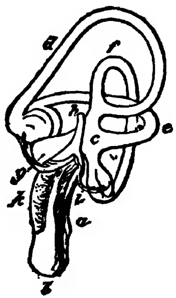


FIG. 84.

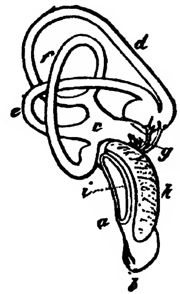


FIG. 85.

FIG. 86.

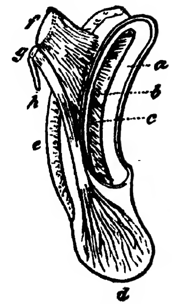


FIG. 87.

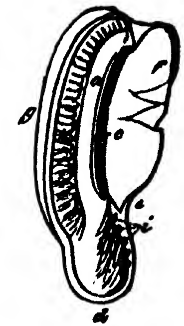


FIG. 88.

FIGS. 84, 85, membranous labyrinth of *Haliaëtus albicilla*, ×2. *a*, *b*, cochlea; *b*, its saccular extremity (or lagena); *c*, vestibule; *g*, its utricle; *d*, anterior or superior vertical semicircular canal; *e*, external or horizontal semicircular canal; *f*, posterior or inferior vertical semicircular canal; *h*, membranous canal leading into aqueduct of the vestibule; *k*, vascular membrane covering the scala vestibuli; opposite this, at *i*, are seen the edges of the cartilaginous prisms in the fenestra rotunda; from the edges of these cartilages proceeds the delicate membrane closing the opening of the cochlea (not shown in the Fig.)

FIG. 86, part of the superior vertical semicircular canal, showing its ampulla (which is the dilatation of the base of any semicircular canal), nerve of ampulla, artery, and connective tissue of the perilymph, ×3. *a*, that part of the vestibule (alveus) next to the ampulla; *b*, the dilatation of the ampulla at its vestibular opening; *c*, where it passes into the canal proper; *d*, the canal furnished with connective tissue of the perilymph along its concave border and sides, as appears clearly at the sections *e* and *f*; *g*, nerve of the ampulla; *h*, artery of the connective tissue, running beneath it, remote from the wall of the duct.

FIG. 87, cochlea, ×3. *a*, external, *b*, internal, cartilaginous prism; *c*, membranous zone; *d* saccular extremity of the cochlea, or lagena; *e*, vascular membrane; *f*, auditory nerve, its middle fascicle penetrating the internal cartilaginous prism, to reach the membranous zone by its terminal filaments; *g*, auditory nerve, its posterior fascicle, running to the most posterior part of the lagena; *h*, filament to ampulla of posterior or inferior vertical semicircular canal.

FIG. 88, section of the cochlea, ×3. *a*, vestibular surface of external cartilaginous prism, extending into *d*, the lagena; *c*, section of the membranous zone; *e*, Huschke's process of the fenestra, which, with the margins of the cartilaginous prisms, affords attachment to the blind sac *f*, occluding the fenestra of the cochlea; *g*, spongy vascular membrane of the scala vestibuli; *h*, auditory lamellæ of Treviranus; *i*, canals in posterior wall of the lagena, by which the nervous filaments enter its cavity.

(From Ibsen's Anatomiske Undersögelser over Örets Labyrinth. 4to, Kjöbenhavn, 1881, p. 17, pl. 1, Figs. 13-17.)

fundibulum would roll along the under stairway, and if nothing stopped the way, would fall through the fenestra rotunda into the

tympanic cavity; this is therefore the *scala tympani*. The first marble would also eventually reach the tympanum, through the vestibule, and out of the fenestra ovalis, if the foot of the stapes were unstepped (in life, of course, both these "windows" are closed by membranous curtains). Now in birds the cochlear cavity and its bony or cartilaginous contents are only the beginnings of such structure—a strap-shaped or tongue-like protrusion from the vestibule, as if a part of the first mammalian whorl, and very incompletely divided into scala vestibuli and scala tympani by a gristly structure (representing the modiolus and its lamina), which proceeds from the bony bar or bridge between fenestra ovalis and fenestra rotunda. (See Figs. 84, 85.) This structure is the most intimate and essential part of the organ of hearing, for upon it spread the terminal filaments of the auditory nerve. A human or any well-developed mammalian cochlea is a thing of marvellous beauty, even as to its bony shell—there is nothing to compare with its exquisite symmetry; while the spiral radiation of the nervous tissue introduces yet other and more wondrous "curves of beauty."

The *vestibule* hardly requires special description; it is simply the central chamber common to the cochlear and canalicular cavities; receiving the mouth of the scala vestibuli of the cochlea; the several mouths of the separate or uniting semicircular canals; opening into tympanum by fenestra ovalis; conducting to meatus auditorius internus by the course of the auditory nerve. In the eagle, if its irregularities of contour were smoothed out, it would about hold a pea.

In the language of human anatomy, the three *semicircular canals* are the (*a*) anterior or superior vertical, the (*b*) posterior or inferior vertical, and the (*c*) external or horizontal; and the planes of their respective loops are approximately mutually perpendicular, in the three planes of any cubical figure. In birds these terms do not apply so well to the situation of the canals with reference to the axis of the body, nor to the direction of the loops; neither is mutual perpendicularity so nearly exhibited. The whole set is tilted over backward to some degree so that the (*a*) "anterior" (though still superior) loops back beyond either of the others; the (*b*) "posterior" loops behind and below the (*c*) horizontal, which tilts down backward; the verticality of the planes of (*a*) and (*b*) is better kept. The canals may be better known as the (*a*) superior (vertical), and (*b*) inferior (vertical), and (*c*) internal (horizontal). Whatever its inclination backward, there is no mistaking (*a*), much the longest of the three, looping high up over the rest, exceeding the petrosal and bedded in the occipital, the upper limb and loop of the arch bas-relieved upon the inner surface of the skull (Fig. 70, *asc*). It makes much more than a semicircle—rather a horse-shoe. The inferior vertical (*b*) loops

lowest of all, though little if any of it reaches farther backward than the great loop of (*a*); it is the second in size; in shape it is quite circular,—rather more than a half-circle. Its upper limb joins the lower limb of (*a*), as in man, and the two open by one orifice in the vestibule; but it is not simple union, for the two limbs, before forming a common tube, twine half-round each other (like two fingers of one hand crossed). The loop of (*b*) reaches very near the back of the skull (outside). The canal (*c*) is the smallest, and, as it were, set within the loop of (*b*), though its plane is nearly the opposite of the plane of (*b*); and the cavities of (*b*) and (*c*) intercommunicate at or near the point of their greatest convexity, farthest from the vestibule. This decussation of (*b*) and (*c*), like the twining inosculation of (*a*) and (*b*), is well known. It may not be so generally understood that there is (in the eagle if not in birds generally) a *third* extra-vestibular communication of the canals. My sections show this perfectly. The great loop of (*a*), sweeping past the decussating-place of (*b*) and (*c*), is thrown into a cavity common to all three. Bristles threaded either way through each of the three canals can all three be seen in contact, crossing each other through this curious extra-vestibular chamber, which may be named the *trivium*, or "three-way" place. (The arrangement I make out does not agree well with the figure of the owl's labyrinth given by Owen, *Anat. Vert.* ii. 134. The trivium is at the place where, in Fig. 84 or 85, the three *membranous* canals cross one another. It does not follow, however, that these contained membranous canals intercommunicate, and it appears from Ibsen's figures that they do not. Study of these admirable illustrations, with the explanations given under them, should make the details perfectly clear to the reader.)

All that precedes relates to the *bony* labyrinth,—the scrolled cavity of the periotic bone. The *membranous labyrinth* is a sac lying loosely in the hollow of the bone, and shaped just like it, lining the hollow of the vestibule and tubes of the semicircular canals. Withdrawn intact, it would be a perfect "cast" of the labyrinth. Originally the sac is also continuous with one in the cavity of the cochlea, called the *membranous cochlea*, which afterward becomes shut off from the main sac. This shut-off cochlear part lies between the scala tympani below and the scala vestibuli above; its interior is the *scala media*. If demonstrable in birds, it must be quite as rudimentary as the other scalæ. The membrane is not attached to the bony walls of the labyrinth, but is separated by a space containing fluid, the *perilymph*, which also occupies the scala vestibuli and scala tympani. A similar fluid, the *endolymph*, is contained in the cavity of the membranous labyrinth, and scala media of the cochlea; in it are found concretions, or *otoliths*, of the same character as the great "stones" so conspicuous in many fishes. This

lymph has a wonderful office—that of *equilibration*, enabling the animal to preserve its equilibrium. The labyrinth and its contained fluid may be likened to the glass tubes filled with water and a bubble of air, by a combination of which a surveyor, for example, is enabled to adjust his theodolite true to the horizontal. Somehow a bird knows how the fluid stands in the self-registering levelling-tubes, and adjusts itself accordingly. Observations made on pigeons show that "when the membranous canals are divided, very remarkable disturbances of equilibrium ensue, which very in character according to the seat of the lesion. When the horizontal canals are divided rapid movements of the head from side to side, in a horizontal plane, take place, along with oscillation of the eyeballs, and the animal tends to spin round on a vertical axis. When the posterior or inferior vertical canals are divided, the head is moved rapidly backwards and forwards, and the animal tends to execute a backward somersault, head over heels. When the superior vertical canals are divided, the head is moved rapidly forwards and backwards, and the animal tends to execute a forward somersault, heels over head. Combined section of the various canals causes the most bizarre contortions of the head and body." (Ferrier, *Funct. of the Brain*, 1876, p. 57.) Injury of the canals does not cause loss of hearing, nor does loss of equilibrium follow destruction of the cochlea. Two diverse though intimately connected functions are thus presided over by the acoustic nerve, —audition and equilibration.

Senses of Taste and Touch: Gustation and Taction.—The hands of birds being hidden in the feathers which envelop the whole body—their feet and lips, and usually much if not all of the tongue, being sheathed in horn, these faculties would appear to be enjoyed in but small degree. While it is difficult to judge how much appreciation of the sapid qualities of substances birds may be capable of, we must not be hasty in supposing their sense of taste to be much abrogated. One who has had the toothache, or teeth "set on edge" by acids, or painfully affected by hot or cold drinks, may judge how sensitive to impressions an extremely dense tissue can be. Persons of defective hearing may be assisted to a kind of audition by an instrument applied to the teeth; and it is not easy to define the ways in which sensory functions may be vicariously performed or replaced. Birds are circumspect and discriminative, even dainty, in their choice of food, in which they are doubtless guided to some extent by the gustatory sensations they experience. As, however, only some human beings make these an end instead of a natural and proper means to an end, the selection of food by birds may be chiefly upon intuitions of what is wholesome. Such purely gustatory sense as they possess is presided over by the

branches of the *glossopharyngeal* nerve which go to the back part of the tongue and mouth. Though the chorda tympani nerve exists, there is no lingual (gustatory) branch of the third division of the fifth cranial nerve. Yet the latter, which goes in mammals to the anterior part of the tongue, is less effectually gustatory than the glossopharyngeal; as we know by the fact that the sensation of taste is not completely experienced until the sapid substance passes to the back of the mouth. Gustation is likewise connected with olfaction; the full effect of nauseous substances, for example, being not realised if the nose is held. From these alternative considerations, each one may estimate for himself how much birds know of sapidity; remembering also, how soft, thick, and fleshy are the tongue and associate parts in some birds, as parrots and ducks, in comparison with birds whose mouths are quite horny.

The beak is doubtless the principal tactile instrument; nor does its hardness in most birds preclude great sensitiveness; as witness the case of the teeth, above instanced. Sensation is here governed by the branches of the fifth nerve. In some birds, in which also the terminal filaments of this nerve are largest and most numerous, the bill acquires exquisite sensibility. Such is its state in the snipe family, in most members of which, as the woodcock, true snipe, and sandpipers, the bill is a very delicate nervous probe. The *Apteryx* also feels in the mud for its food, enjoying moreover the unusual privilege of having its nose at the end of its long exploration. Ducks dabble in the water to sift out proper food between the "strainers" with which the sides of their beaks are provided; and the ends of the maxillary and mandibular bones themselves are full of holes, indicating the abundance of the nervous supply (Fig. 63).

The senses of birds and other animals are commonly reckoned as five—a number which may be defensively increased—as by a sixth, the muscular sense, which gives consciousness of strain or resistance, apart from purely tactile impressions; and perhaps a seventh, the faculty of equilibration, which has a physical mechanism of its own, at least as distinct and complete as that of hearing. The ordinary "five senses" are curiously graded. *Taction* connotes qualities of matter in bulk, as density, roughness, temperature, etc. *Gustation*, matter dissolved in water—fluidic. *Olfaction*, matter diffused in air—aeriformed. *Audition*, atmospheric air in undulation. *Vision*, an ethereal substance in undulation. All animals are probably also susceptible of *biogenation*, which is the affection resulting from the influence of biogen; a substance consisting of self-conscious force in combination with the minimum of matter required for its manifestation.[1]

[1] The reader who may be interested to inquire further in this direction is referred to a publication entitled :—*Biogen: A Speculation on the Origin and Nature of Life.*

c. MYOLOGY: THE MUSCULAR SYSTEM

Muscular Tissue consists of more or fewer amœbiform animals; separate colonies of which creatures, isolated in various parts of the body, compose the individual different muscles. They are enveloped in fibrous tissue, the sheets of which are called *fasciæ*, and the ends of which, usually attached to bones by direct continuity with the periosteal covering of the latter, form tendons and ligaments. The muscle-animals belong to a genus which may be termed *Myamœba*, differing from other genera of the amœbiforms which compose the body of a bird less in their physical character of being elongated and spindle-shaped, or even filiform, than in their physiological character of *contractility*. Under appropriate stimulus, as the passage of a current of electricity, or the wave of biogen-substance which constitutes a "nerve-impulse," *Myamœbæ* shorten and thicken, tending towards a state of tonic contraction which, if completed and long sustained, would cause them to become encysted as spherical bodies; but extreme contraction is never long continued. By alternate contraction and relaxation all the motions of the body in bulk are effected. The capacity of, or tendency to, contraction is called the *tonicity* of muscular fibre. The simultaneous contraction of any colony of *Myamœbæ* pulls upon the attachment of the muscle at each of its ends; in some cases approximating both ends; oftener moving the part to which one end is attached, the other being fixed. The action of a muscle is upon the simplest mechanical principles,—nothing more or less than pulling upon a part, as by a rope, the line of traction being exactly in the line of contraction of the muscle; though it is often ingeniously changed by the passage of tendons around a corner of bone, or through a loop of fibrous tissue, as if through a pulley. Such movements as those of a turtle protruding its head, or a bird thrusting its beak forward, where muscle seems to *push*, are fallacious; when analysed, the motion is invariably resolved into simple *pulling*. The swelling up of a muscle in contracting must indeed impinge upon neighbouring parts and shove them aside; but that is an extrinsic result. Muscles contract most powerfully under resistance to their turgescence: what is effected by the fasciæ which bind them down;—what the athlete seeks to increase by bandaging his swelling *biceps*. There are two species of *Myamœba*. *M. striata* is the ordinary striped fibre of voluntary motion, and also of some motion not

Abridged from a paper on the "Possibilities of Protoplasm," read before the Philosophical Society of Washington, 6th May 1882. By Dr. Elliott Coues, etc. Washington, Judd and Detweiler. 8vo, 27 pp. Fifth edition. Boston, Estes and Lauriat, 1887.

under control of the will, as that of the heart. This species is usually of a rich red colour (pale pink in many birds of the grouse family), and is the ordinary "flesh" of the body. The other species, *M. lævis*, composes the pale or colourless smooth fibre of the involuntary muscles, as those of the intestines, the gullet, etc. A species of contractile tissue commonly referred to the genus *Desmamœba* (indifferent connective-tissue cells) is very near *Myamœba lævis;* example, mammalian *dartos.* The movements of erectile organs, as the neat combs over the eyes of grouse, or the turkey's caruncles, are not in any sense *myamœbic*, but depend mechanically upon influx of blood.

The Muscular System of Aves can only be touched upon; it is impossible in my limits to even name all the muscles, much less describe them. I can only note the leading peculiarities, and present a figure in which the principal muscles are named.

The subcutaneous sheet of muscle (of which the human "muscles of expression" and *platysma myoides* are segregations) is broken up in birds into a countless number of little slips which agitate the feathers collectively, and especially the great quills of the wings and tail. There are estimated to be 12,000 in a goose. The prime peculiarity of birds' musculation is the enormous development of the *pectorales*, or breast muscles, which operate the wings. The great pectoral, *p. major* or *p. primus*, arises from the sternal keel, when that special bony septum between the fellow-pectorals exists, and from more or less of the body of the sternum, passing directly to the great pectoral or outer ridge of the humerus, near the upper end of that bone. Its origin may even exceed the limits of the sternum, invading the clavicle, etc.; it may unite with its fellow. It is the depressor of the humerus, giving the *downward* stroke of the wing. The next pectoral, *p. secundus* or *p. medius*, arises from much or most of the sternum not occupied by the first, under cover of which it lies; it passes also the humerus, but by an interesting way it has of running through a pulley at the shoulder it elevates that bone, giving the *upward* wing-stroke. A third pectoral, *p. tertius* or *p. minimus*, arising from sternum, and often contiguous parts of the coracoid bone, passes directly to the humerus, supplementing the action of the first. A fourth muscle in many birds acts upon the humerus from the sternum or coracoid, particularly the latter. These four differ greatly in their relative development. Such extent of the sternum and pectoral muscles correspondingly reduces that of the belly-walls, and the abdominal muscles are consequently scanty. Fixity of the spinal column in the dorsal region diminishes the musculation of that part, the spinal muscles being much better developed in the cervical region; where, in cases of some of the long-necked birds, there are curious con-

trivances for the mechanical advantage of the muscle in flexing and extending this mobile part of the body. Muscles of the hyoidean apparatus acquire a singular development in woodpeckers. The lower jaw is depressed particularly by muscle inserted into the end of the mandible; the upper is elevated by particular muscles operating the pterygoid and quadrate bones. Temporal, masseteric, and ordinary pterygoid muscles close the jaws. They are unsymmetrical in *Loxia*.

The *diaphragm*, the musculo-membranous partition which in mammals divides the thoracic from the abdominal cavity, is only represented in birds in a rudimentary condition. Macgillivray has figured that of the rook as consisting of three fleshy slips, *v*, *v*, *v*, passing from as many ribs, 4, 5, 6, to the pleural sac of the lungs, *t*, *t*, in Fig. 101. It is best developed in the *Apteryx*.

The remarkable specialisation of both limbs,—the former for flight, the latter for the perfectly bipedal locomotion which only birds besides man enjoy,—results in corresponding peculiarities of the muscular mechanism. Muscles beyond the shoulder are greatly reduced in number and complexity from an ordinary quadrupedal standard; those of the legs are rather increased, and their configuration, relative size, and to some extent their relations, are so much changed, that great difficulty is experienced in identifying them with the corresponding muscles of quadrupeds. The result is great confusion in their nomenclature, which is still shifting, though much has been done of late to give it precision. Attention has recently been called by Garrod to the classificatory value of certain muscles of the limbs. The *tensor patagii*, that muscle or those muscles which may have elastic tendons, and by which the folds of skin in the angles of the wing-bones are regulated, may have different characters in different groups of birds. It has long been known that particular muscles of the hind limb are in direct and important relation to the prehensile power of the toes, and consequently co-ordinated with the insessorial or the reverse character of the foot. In the highest birds, *Passeres*, the foot grasps with great facility, owing to the distinctness or individuality of the *flexor longus hallucis*, or bender of the hind toe. The *ambiens* (Lat. *ambiens*, going around) is a muscle of which Garrod has even made so much as to divide all birds into two primary groups according to whether they possess it or not. The ambiens arises from the pelvis about the acetabulum, and passes along the inner side of the thigh; its tendon runs over the *convexity* of the knee to the outer side, and ends by connecting with the *flexor digitorum perforatus*—one of the muscles which bend the toes collectively. When this arrangement obtains, the result is that when a bird goes to roost, and squats on its perch, the toes automatically clasp the perch by the strain upon

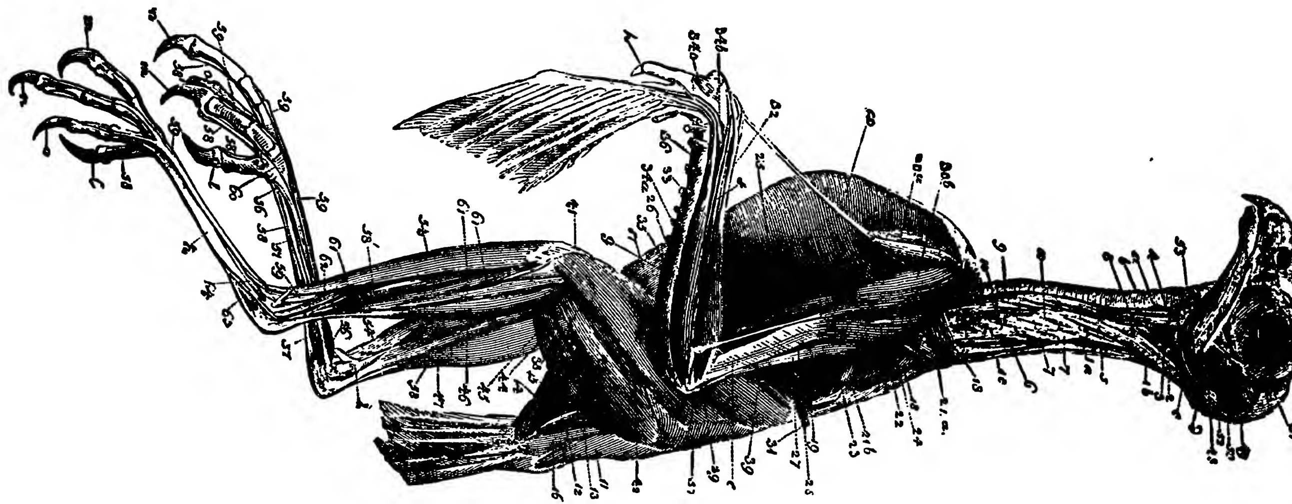


FIG. 89.—Muscles of a bird (*Accipiter nisus*), after Carus, *Tab. Anat. Comp.*, i. 1828, pl. 4. *a*, pharynx; *b*, trachea; *c*, hyoid bone; *d*, ear; *e*, humerus; *f*, radius; *g*, ulna; *h*, radial finger; *i*, tibia; *k*, metatarsus; *l*, hind toe; *m*, inner toe; *n*, middle toe; *o*, outer toe. 1, biventer cervicis, with central tendon 1 *a*, and upper 1 *b*, and lower 1 *c*, belly. 2, complexus. 3, flexor capitis lateralis. 4, flexor longus capitis. 5, extensor magnus cervicis. 6, descendens cervicis. 7, 7, semispinales. 8, flexor superior capitis. 9, flexor inferior or longus capitis. 10, 10, intertransversales. 11, levator coccygis. 12, depressor coccygis. 13, cruro-coccygeus (ilio-coccygeus?). 14, pubococcygeus. 15, ischiococcygeus. 16, lateralis quartus (quadratus coccygis, to tail-feathers). 17, obliquus externus abdominis. 18, cucullaris (trapezius). 19, serratus magnus. 20, pectoralis major. 21, *a*, *b*, latissimus dorsi. 22, deltoid. 23, suprascapular. 24, coracobrachialis. 25, biceps brachii. 26, supinator longus. 27, anconeus longus (part of "triceps") 28, anconeus brevis. 29, anconeus brevissimus. 30 *a*, 30 *b*, tensor patagii, carpal and radial parts. 31, tensor patagii posterior. 32, extensor metacarpi longus. 33, extensor metacarpi brevis. 34 *a*, flexor digitorum sublimis. 34 *b*, flexor digitorum profundus. 34 *c*, flexor brevis pollicis. 35, flexor metacarpi radialis. 36, flexor (meta-) carpi ulnaris. 37, glutæus maximus. 38, adductor femoris primus. 39, sartorius. 40, latissimus femoris. 41, gracilis=*ambiens*; only its tendon in sight. 42, vastus. 43, biceps cruris. 44, semimembranosus. 45, semitendinosus. 46, 46, 47, gastrocnemius. 48, digastricus (chief opener of the mouth). 49, temporal. 50, long ligament. 51, cutaneous muscle of scalp. 52, masseter. 53, a muscle of the hyoid bone. 54, tibialis anticus. 55, tibialis posticus. 56, extensor hallucis. 57, flexor hallucis. 58, flexor digitorum profundus or perforans, seen in various places: long and short head, and several tendons. 59, extensor longus digitorum, tendons seen in various places. 60, abductor digiti interni. 61, 61, 61, flexores digitorum perforati. 62 peronæus. 63, abductor minimi digiti. 64, abductor hallucis.

the ambiens that ensues as soon as the leg is bent upon the thigh, and the tarsus upon the leg, the weight of the bird thus holding it fast upon its perch. The effect is as if an elastic cord were tied to the hip joint, thence directed over the front of the knee and back of the heel and so on to the ends of the toes. Obviously, such a cord would be strained when the limb is bent, relaxed when the limb is straightened out. The reader may observe a corresponding effect of the muscular arrangement of his forearm by throwing the hand as far back as possible; the fingers tend to close by the strain on the flexors in passing over what is a convexity of the wrist when the hand is in that position. *Passeres* have no ambiens, the perfection of their feet in other respects answering all purposes. Birds having it are termed *homalogonatous* or "normally-kneed" (Gr. ὁμαλός, *homalos*, from ὁμός, *homos*, like, even, etc.; γόνυ, γόνατος, *gonu*, *gonatos*, knee); those wanting it are called *anomalogonatous*, "abnormally-kneed." The distinction prevails with much applicability to various large groups of birds, and does good duty in diagnosis when duly connected with other characters; but surely should not give name to primary groups founded upon it! Other muscles of the leg much used by the same sagacious and zealous anatomist are the *femorocaudal*, *accessory femorocaudal*, *semitendinosus*, and *accessory semitendinosus*. The whole five of these muscles "vary; any one or more than one may be absent in different birds; . . . the constancy of the peculiarities in the different individuals of each species, or the species of each genus, and very generally in the genera of each family, makes it evident to any one working at the subject that much respecting the affinities of the different families of birds is to be learnt from the study of their myology, in connection with the peculiarities of their other soft parts; and that these features will, in the long run, lead to a more correct classification than one based on the skeleton alone, becomes almost equally certain." (Garrod, *P. Z. S.*, 1873, p. 630.)

d. ANGIOLOGY: THE VASCULAR OR CIRCULATORY SYSTEMS

Blood and Lymph are the two media by the circulation of which throughout the body the various amœboid animals which compose the tissues are fed, their waste repaired, and their dead parts removed. Each species of *Amœba* has the faculty of selecting from the constituents of blood and lymph its appropriate food; and of converting such nourishment into its own proper substance. Refuse matters are either drained off by the kidneys and voided as excrement, or swept by the current of blood into the lungs and there cremated. The stream of lymph is a feeder to the blood, and when the mingled currents are no longer distinguishable has become

blood. The machinery of circulation is two sets of vessels—the *hæmatic*, or vascular system proper, consisting of the heart, arteries, veins, and capillaries, for the blood-circulation; and the *lymphatic*, consisting of lymph-hearts and vessels, for the flow of lymph. The lymphatics, converging from all parts of the body, and especially from the intestines, end in vessels which pour the lymph into the veins of the neck. The heart is the central organ of the blood-circulation, by which that fluid is pumped into all parts of the body through the *arteries* or *efferent* vessels; straining through the net-work of *capillaries*, it returns to the heart through the *veins*, or *afferent* vessels. The set of efferent vessels is the *arterial system*; that of afferent vessels is the *venous system*. The blood in arteries excepting the *pulmonary* is bright red; that in veins excepting the pulmonary is dark red. The change from bright to dark occurs in the capillaries of the system at large; the change from dark to bright only in the capillaries of the lungs and air-sacs. The *systemic* blood circulation is completely separated from the *pulmonic* in all animals in which, as in birds, the right and left sides of the heart are separated from each other; such circulation is said to be *double*; that is, arterial and venous blood only mingles in the capillaries, whether of the lungs or others, and therefore at the *periphery* of the vascular system: the heart being the centre of that system. Blood, in all or some of its constituents, permeates absolutely every tissue of the body. Those tissues whose capillaries are large enough for the passage of all the constituents of blood are said to be *vascular*; those which only feed by sucking up certain constituents of the blood, and have no demonstrable capillaries, are called *non-vascular*. But nutrient fluid penetrates the densest tissue, as the dentine of teeth; no permanent tissues are really non-vascular, or they would soon die, as do feathers, which require to be renewed once a year or oftener.

Lymph and the lymphatics are noticed further on. Blood consists of water in which several ingredients are dissolved, and certain solid bodies are suspended. Its water is salted, albuminated, fibrinated, and corpusculated. The proportions, which vary in different birds and at different times in the same bird, are in round numbers: water 80, fibrine and corpuscles 15, albumen and salts 5 = 100 parts. Withdrawn from the body and allowed to settle, blood separates into two parts, *serum* and *coagulum*. The serum is the clear yellowish salty albuminous water; the clot is the fibrine, in the meshes of which are mired the corpuscles, reddening the whole mass. The *plasma*, plasm or plastic material of the blood, is its substance dissolved in water; that is to say, *minus* the solid corpuscles. These latter interesting little bodies are a myriad of minute animals, which swim in the life-current, and are named

Hæmatamœba cruentata. They have been supposed to be of two species; but the so-called white blood corpuscles, or *leucocytes*, indistinguishable from lymph corpuscles, are simply the formative stages of the red blood-discs. In its early colourless stage, the *Hæmatamœba* is a nucleated mass of protoplasm (*protoplasm* is the indifferent substance out of which all animal tissue is derived), of no determinate size or shape, exhibiting active amœboid movements. Later in the life of the minute creature, it passes into a sort of encysted state, in which it reddens and acquires definite dimensions and configuration. In birds these "blood-discs" are flat, elliptical, and *nucleated*, that is, containing a kernel; they average in the long diameter $\frac{1}{2100}$, in the short, $\frac{1}{3800}$, of an inch. Thus they differ decidedly from the flat, circular, non-nucleated, red blood-discs of *Mammalia*, which latter are supposed to be rather *free nuclei* than perfected *Hæmatamœbæ.* The red colour of blood is entirely due to the presence of these unicellular animals. The energy of respiration, and corresponding activity of circulation in birds, make them *hæmatothermal*, or hot-blooded; the pulse is quickest, the blood hottest, and richest in organic matter, in these of all animals.

The Heart is a hollow muscular organ, at the physiological centre of the hæmatic vascular system. Its muscle presents the principal exception to the rule, that the contractility of *Myamœba striata* (see p. 285) is subject to voluntary control. It is the most industrious organ of the body, never ceasing its rhythmic *systole* and *diastole*, or contraction and dilatation, from the moment of the first pulsation in the contractile vesicle which begins it, to that when the "muffled drum" gives the last beat of the "funeral march to the grave." The arteries are the elastic, thick-walled, branching tubes which leave the heart on their way to the body at large; their pulsations, over which the vasomotor nervous system presides, are isochronous with the heart-beats, and arterial blood thus flows in jets. The veins are the vessels converging from all parts; thin-walled, less elastic, with more equable current. The capillaries are the communicating vessels, of such size as just to permit the Hæmatamœbas to pass through; their network represents the terminations of arteries and the commencements of veins. The heart in adult birds is completely double; *i.e.* the right and left sides are perfectly separated. It is also completely four-chambered; *i.e.* there is an *auricle* and a *ventricle* on each side, which communicate; in embryonic life the two auricles communicate by the *foramen ovale*, which afterward closes. Arteries proceed from the strong muscular ventricles; veins are received by the weaker auricles. The course of the blood is: From the body, excepting the lungs, it comes dark and heavy with products of decomposition, through the *caval* veins

into the *right auricle;* from right auricle through the auriculo-ventricular opening into *right ventricle;* from right ventricle through the *pulmonary arteries* to the lungs; in the capillaries of which it is relieved of its burden. There decarbonised and oxygenised, the bright red aërated blood returns through the *pulmonary veins* to the *left auricle;* through the corresponding auriculo-ventricular opening to the *left ventricle,* which pumps it out through the *aorta* and other arteries to the capillaries, and so to the veins and heart again. Thus the pulmonary *arteries* convey black blood, the pulmonary *veins* red blood; the reverse of the usual course. Before lungs come into play, in the egg, the blood is purified in the *allantois,* an embryonic organ which then sustains a respiratory function. Besides the pulmonary there is another special circulatory arrangement, the *hepatic portal* system of veins, by which blood coming from the *chylopoetic* viscera (stomach, intestines, etc., which make chyle in the process of digestion) strains through the liver before reaching the heart. There is no *renal* portal system in birds.

The heart of birds is not peculiar in its conical shape, but is more median in position than in mammals. There being no completed diaphragm, the pericardial sac which holds it is received in a recess between lobes of the liver. The right ventricle is much thinner-walled than the left; the auricles have less of the elongation which has caused their name ("little ears" of the heart) in mammals. The *right* auriculo-ventricular valve, which prevents regurgitation of blood, instead of being thin and membranous, is a thick fleshy flap which during the ventricular systole applies itself closely to the walls of the cavity. The pulmonary artery and the aorta are each provided at their origination with the ordinary *three* crescentic or semilunar valves, as in mammals. The pulmonary artery arises single, forking for each lung. The pulmonary veins are *two.* The systemic veins, or *venæ cavæ,* bringing blood from the body at large, are *three*—two *precaval,* from head and upper extremities, one *postcaval,* from trunk and lower extremities. The *aorta,* almost immediately at the root of that great trunk, Figs. 90-95, *h,* divides into three primary branches; right, *ri,* and left, *li, innominate* arteries, conveying blood to the neck, head, and upper extremities; and main *aortic, a,* which curves over to the *right* (left in mammals) and supplies the rest of the body. More precise statement is, perhaps, that the aortic root, *h,* first gives off the left innominate, *li,* then at once divides into right innominate, *ri,* and main aortic trunk, *a,* (right). It represents the *fourth* primitive aortic arch of the embryo. On the whole, the avian heart is a great improvement on that of most reptiles, though nearly resembling that of *Crocodilia;* it is substantially as in any mammal, though differing in its fleshy right auriculo-ventricular valve, two instead

of one precaval vein, right instead of left aortic arch, and mode of origin of the primary aortic branches.

The zoological interest of the avian blood-vessels centres in the *carotid arteries*, which, with the *vertebral* arteries, supply the neck and head. The carotids may be single or double; and other details of their disposition correspond well with certain families and orders of birds. They are the first branches of the innominates. In most

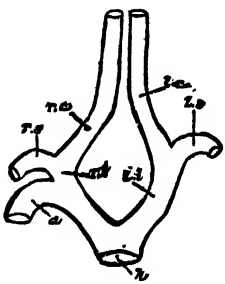


FIG. 90.

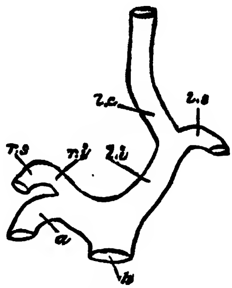


FIG. 91.

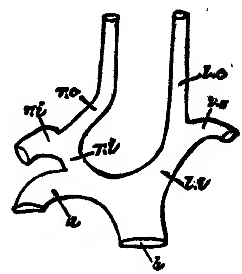


FIG. 92.

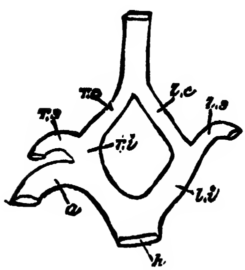


FIG. 93.

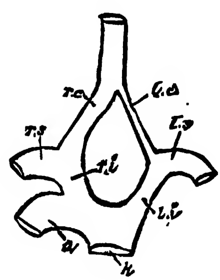


FIG. 94.

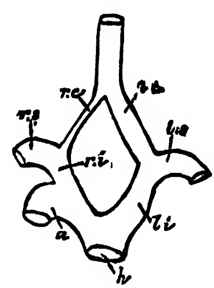


FIG. 95.

FIGS. 90-95.—Diagrams of carotid arteries of birds: *h*, root of aorta; *a*, arch of aorta, to the right side; *li*, left innominate; *ri*, right innominate; *ls*, left subclavian; *rs*, right subclavian; *lc*, left carotid; *rc*, right carotid. (1) Fig. 90. *Aves bicarotidinæ normales*, with two carotids, both alike. (2) Fig. 91. *Aves lævo-carotidinæ*, with left carotid only. (3) Fig. 92. *Aves bicarotidinæ abnormales*, certain parrots, with two carotids, not alike. (4, 5, 6) *Aves conjuncto-carotidinæ*, with two carotids, which speedily unite in one. (4) Fig. 93, bittern, both alike. (5) Fig. 94, flamingo, left very small. (6) Fig. 95, cockatoo, right very small. (Copied by Shufeldt from Garrod.)

birds, there is but one carotid, the left; in a few, one, formed by early union of two; in many, two, long distinct. The arrangement will be perceived by the diagrams taken from Garrod's admirable paper (*P. Z. S.*, 1873, p. 457). In nearly the words of this author: 1. In what may be termed the *typical* arrangement (though it is not the usual one), two carotids, of equal size or nearly so, run up the front of the neck, converging till they meet in the middle line, and so continue up to the head, on the front of the bodies of the

heavy with effete carbonaceous matters, is there relieved of its burden and aërated by the action of oxygen; the products of combustion being exhaled in the form of carbonic dioxide and water. Aside from the proper lung-tissue, the capillary substance of the immense air-sacs tends to the same result. There is likewise, in birds, a lesser system of ventilation, by which air is admitted to cranial bones through the Eustachian tubes; but this is unconnected with the proper respiratory office. Pulmonary tissue consists chiefly of a wonderful net (a *rete mirabile*) of capillaries, interlacing in every direction, bound together and supported by fine connective tissue, and invested with membrane so delicate that their walls seem naked, their exposure to the air being thus very thorough. Air gains such intimacy with the capillaries through the *larynx*, *trachea* (Fig. 101, *o*), and *bronchial tubes* (*r*, *r*), these being the primary air-passages. But all the bronchial tubes do not subdivide into the ultimate air-cells; some large ones run through the lung, pierce its surface (as at *u*, *u*, Fig. 101), and end in that system of enormous air-spaces for which the respiratory system of birds is so remarkably distinguished,—like a heap of soap-bubbles, blown up *en masse* from a bowl of fluid; the extra-pulmonary air-spaces being the larger superficial bubbles, the minute vesicles of lung-tissue proper being little bubbles just formed. In this way air penetrates even the hollow skeleton of most birds.

The Lungs of Birds (Fig. 101, *t*, *t*), notwithstanding their heated energy of respiration, are anatomically more like those of reptiles than of mammals. They are not shut by a diaphragm in a special division of the great thoracic-abdominal cavity of the body, but extend from the apex of the chest as far as the kidneys, in the pelvic region. They are not divided into lobes, as in mammals, nor do they as in that class float freely in the chest by their mooring at their roots; nor, again, are they completely invested by a serous membrane forming a closed pleural cavity. They are fixed in the dorsal region of the general cavity, covered in front with pleura, with which slips of the rudimentary diaphragm (*v*, *v*, *v*) are connected; but on the dorsal surface are accurately moulded to the intercostal spaces, showing the impressions of the ribs and vertebræ,—just as the lobulated kidneys are stamped with the sacral inequalities of surface. They are, as usual, two, right and left; their "roots" are the bronchi (*r*, *r*), the pulmonary arteries and veins, nerves, and connective tissue.

The Pneumatocysts.—A bird is literally inflated with these great membranous receptacles of air, and draws a remarkably "long breath,"—all through the trunk of the body, in several pretty definite compartments; in many, or most, or all, of the bones; in many intermuscular spaces; in some birds also throughout the cellular tissue immediately beneath the skin. These cysts vary so

much in extent and disposition as to be not easily described except either in the most general terms already used, or with particularity of detail for different species. According to Owen, however, the usual disposition is: An *interclavicular* air-space, quite constant: this, with its *cervical* prolongations, furnishes the great "air-drums" of the pinnated grouse and cock-of-the-plains. *Anterior thoracic*, about the roots of the lungs. *Lateral thoracic*, prolonged to *axillary*, and to spaces and passages in the wings, including the hollow humerus. Large *hepatic* or *posterior thoracic*, about the lower part of the lung and the liver. *Abdominal*, right and left, of great size, from the lower part of the lung where the longest bronchial tubes open very freely; extending to *pelvic* and *inguinal* compartments, whence *femoral* sacs, the hollow of the femur, etc. The *subcutaneous* cells are enormously developed in the pelican and gannet; the extensive areolar tissue being thoroughly pneumatic, and furnished with an arrangement of the cutaneous muscle (*panniculus carnosus*) whereby, apparently, the air may be rapidly and forcibly expelled by compression. A similar muscle develops in some birds in connection with the interclavicular air-space. (The pneumaticity of the skeleton has been already treated.)

The purpose of this extensive respiratory apparatus is thus dwelt upon by the great English anatomist just cited: "The extension from the lungs of continuous air-receptacles throughout the body is subservient to the function of respiration, not only by a change in the blood of the pulmonary circulation effected by the air of the receptacles on its repassage through the bronchial tubes; but also, and more especially, by the change which the blood undergoes in the capillaries of the systemic circulation which are in contact with the air-receptacles. The free outlet to the air by the bronchial tubes does not, therefore, afford an argument against the use of the air-cells as subsidiary respiratory organs, but rather supports that opinion, since the inlet of atmospheric oxygenated air to be diffused over the body must be equally free. A second use may be ascribed to the air-cells as aiding mechanically the action of respiration in birds. During the act of inspiration the sternum is depressed [lowered from the back-bone in horizontal position of a bird], the angle between the vertebral and sternal ribs made less acute, and the thoracic cavity proportionally enlarged; the air then rushes into the lungs and thoracic receptacles, while those of the abdomen become flaccid; when the sternum is raised or approximated towards the spine, part of the air is expelled from the lungs and thoracic cells through the trachea, and part driven into the abdominal receptacles, which are thus alternately enlarged and diminished with those of the thorax. Hence the lungs, notwithstanding their fixed condition, are subject to due compression through the medium of

the contiguous air-receptacles, and are affected equally and regularly by every motion of the sternum and ribs. A third use, and perhaps the one which is most closely related to the peculiar exigencies of the bird, is that of rendering the whole body specifically lighter; this must necessarily follow from the desiccation of the marrow and other fluids in those spaces which are occupied by the air-cells, and by the rarefaction of the contained air from the heat of the body. . . . A fourth use of the air-receptacles relates to the mechanical assistance which they afford to the muscles of the wings. This was suggested by observing that an inflation of the air-cells in the gigantic crane (*Ciconia argala*) was followed by an extension of the wings, as the air found its way along the brachial and antibrachial cells. In large birds, therefore, which, like the argala [or like the wood-ibis, *Tantalus loculator*], hover with a sailing motion for a long-continued period in the upper regions of the air, the muscular exertion of keeping the wings outstretched will be lessened by the tendency of the distended air-cells to maintain that condition. It is not meant to advance this as other than a secondary and probably partial service of the air-cells. In the same light may be regarded the use assigned to them by Hunter, of contributing to sustain the song of birds and to impart to it tone and strength. It is no argument against this function that the air-cells exist in birds which are not provided with the mechanism necessary to produce tuneful notes; since it was not pretended that this was the exclusive and only office of the air-cells." (Owen, *Anat. Vert.*, ii. 1866, p. 216.)

Though nothing like them exists in mammals, it must not be inferred that these air-pouches are unique in birds. The general pulmonary mechanism is reptile-like, and the ornithic development is simply a logical extreme of arrangements found in reptiles and lower vertebrates,—even to the swim-bladder of a fish, which is morphologically and homologically pulmonary, though fishes' *gills* are functionally, and therefore analogically, their lungs, *i.e.* their respiratory apparatus.

The Trachea (Gr. τραχεῖα, *tracheia*, rough) or "asper-artery" answers perfectly to its English name, windpipe. It is the tube which conveys air to and from the lungs (Fig. 101, [1], *o* to *q*). It commences at the root of the tongue by a chink in the floor of the mouth (Fig. 101, [8], *c*), runs down the neck in front between the gullet and the skin, and ends below by forking into right and left *bronchus* (Fig. 101, [1], *r*, *r*). It is composed of a series of very numerous gristly or bony rings connected together by elastic membrane. Lengthening and shortening, effected by muscles to be presently noted, is permitted by a very ingenious and interesting construction of these rings, which will be clearly understood with the help of the figures (96, *a*, *b*, 97, [1], [2],) borrowed from Macgillivray's

admirable account. When contracted, the rings look like an alternating series of lateral half-hoops, as in Fig. 96, a; when stretched to the utmost, as in Fig. 96, b, they are clearly seen to be annular, or completely circular. The curious bevelling of the right and left sides of each ring alternately is shown in Fig. 97, 1, 2; and Fig. 97, 1, 2, represents the same two rings put together. The principle by which any two rings slip partly over each other on alternate sides is something like that upon which a cooper fastens the ends of any one barrel-hoop without any nailing or tying. The rings are in some birds perfectly cartilaginous: in most they become osseous. The trachea is moved by lateral muscles, which not only shorten the tube by approximating the rings, but also drag the whole structure backward, by their attachment to the clavicle and sternum. The strip, or two strips, of muscle lying upon each side of the trachea, is the *contractor tracheæ* (Fig. 101, 1, *ss*, *ss*); the most anterior, when there are two, as soon as it leaves the tube to go to the clavicle, becomes the *clidotrachealis*, or *clidohyoid*, Fig. 101, 1, *f*, *f*; the other is similarly the *sternotrachealis*. The latter may be a direct continuation of the contractor, as in Fig. 101, 1, the loose strips under *q*, or apparently arise separately from the side of the lower end of the tube, as in Fig. 101, 16, *e*. (Other muscles are to be described with the larynx superior and inferior.) The trachea is long in birds, proportionate to the extension of the neck; it is very flexuous, following with ease the bends of the neck in which it lies so loosely. Its cross section is oval or circular; but all that relates to the configuration and course of the pipe requires special description,—so variable is the organ in different birds. It is subject to dilatations and contractions in any part of its extent, and to deviations from its usual direct course to the lungs. Minor modifications must be passed over. The most remarkable expan-

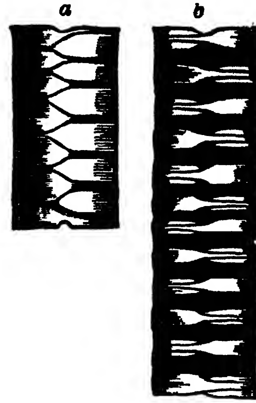


FIG. 96.—*a*, an inch of trachea, contracted to the utmost, the rings looking like alternating half-rings; *b*, the same, stretched to two inches, the rings evidently complete, with intervening membrane. (After Macgillivray.)

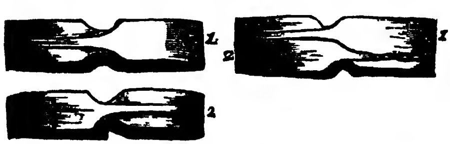


FIG. 97.—1, 2, left-hand, two tracheal rings, separate, as in Fig. 96, *b*; 1, 2, right hand, the same put together, as in Fig. 96, *a*. (After Macgillivray.)

sions of the lower part of the tube occur in many sea-ducks and mergansers (*Fuligulinæ*, *Merginæ*), and some other birds; several lower rings of the trachea being enormously enlarged and welded together into a great bony and membranous box, of wholly irregular, unsymmetrical contour. Such a structure, represented in Figs. 3 and 98, is termed a *tracheal tympanum*, or *labyrinth*. It is not a part of the voice-organ proper, but may act as a reverberatory chamber to increase the volume of the sound, without however modulating it. Being chiefly developed in the male, it is a kind of secondary sexual organ. The vagaries of the windpipe are still more remarkable. Very generally, in cranes and swans, the trachea enters the keel of the sternum, which is excavated to receive it, and where it forms one or more coils before emerging to pass to the lungs. This curious winding is carried to an extreme in *Grus americana*, the whooping crane, in which the windpipe is about as long as the whole bird, and about half of it—over two feet of it!—is coiled away in the breast-bone (Fig. 99). The same thing occurs in *G. canadensis* to a less extent (Fig. 100). In a guinea-fowl, *Gutter acristata*, a loop of the trachea is received in a cup formed by the apex of the clavicles. In various birds, as some of the curassows (*Cracidæ*), the capercaillie (*Tetrao urogallus*), a goose, *Anseranas semipalmata*, and the female of the curious snipe, *Rhynchæa australis*, the trachea folds between the pectoral muscles and the skin.

FIG. 98.—Bony labyrinth at bottom of the trachea of the male of *Clangula islandica*, seen from behind, nat. size. Dr. R. W. Shufeldt, U.S.A.

The Larynx (the Gr. name, λάρυγξ, *larugx*) is the peculiarly modified upper end of the trachea (Fig. 101, [1], and [8] *to* [12]). In mammals it is a complicated voice-organ, containing the vocal chords and other consonantal apparatus; in birds the construction is simpler, as the larynx merely modulates the sound already produced in the lower end of the tube. It lies in the floor of the mouth, at the root of the tongue, between the forks of the hyoid bone, resting upon the urohyal. Besides its attachments of mucous and other membrane, *it is connected with the hyoid bone by a pair of thyro-hyoid muscles* ([8], [1], [1]), *and usually with the rest of the trachea by* prolongations of the sterno- and clido-tracheales. It is usually a small, simple, conical "mouthpiece" of the pipe ([4], *a*), without the

dilatation which renders the corresponding structure—the "Adam's apple,"—so conspicuous in the human throat. Below, it communicates directly with the pipe: above, it opens into the mouth by the *glottidean fissure*, or *rima glottidis* ([8], *c*), a median lengthwise chink, which opens and shuts as its sides diverge or close together, and which is further defended in front by a folding of the mucous membrane of the mouth, constituting a rudiment of that curious trap-door arrangement which, when fully developed, is called the *epiglottis* ([8], *d*, *e*). Exclusive of two *broken* upper rings of the trachea ([6], *g*), the cartilages (or oftener bones,—for they generally ossify) of the larynx are five. One is a large single median and inferior piece, the *thyroid*, or shield-piece ([4], [6], [7], *a*), forming the most substantial part of the structure. It is somewhat triangular or oblong, running to an obtuse end in front; and with sides and posterior angles which curl upward behind. To its lateral posterior corner is attached on each side the small "horn" or *corniculum laryngis* ([5], [6], [7], *b*). There is a small median upper posterior piece, supposed to represent all there is of the *cricoid* ([5], [7], *c*), which in man makes a ring around the larynx below the thyroid. To the cricoid, as to a base, are attached a pair of straight slender *arytenoids* ([6], [7], *d*), projecting forward along the upper surface of the larynx: these form the *rima glottidis*,—the fissure of the glottis being between them. The arytenoids are attached in front by slender ligaments to the end of the thyroid ([5], the little slips between *d* and *e*), and they are supplemented by cartilaginous edges ([6], *f*, *f*); but there are no true vocal chords. Besides the extrinsic thyrohyoid muscles, which pass from the larynx to the tongue-bone, the laryngeal parts are operated by intrinsic muscles, the sum of the motion given by which is the opening and shutting of the glottis by drawing apart or pulling together the arytenoids. Four pairs of such muscles are described for some birds. As named and figured by Macgillivray for the rook, there are: the *thyroarytenoids*, which are the openers of the glottis ([9], [2,2]); the *oblique arytenoids* ([10], [3,3]); the *thyrocricoids* ([11], [4,4]); and the *posterior thyrocricoids*, ([11] and [12], [5,5]).

The Syrinx (Gr. σύριγξ, *surigx*, a pipe) or Lower Larynx is the voice-organ of birds; in most respects a more complicated structure than the larynx proper, and one so differently constructed in different birds that it affords characters of great significance in classification. The highest group of *Passeres*, for example, is signalised by the elaboration of this musical organ, the marvellously adroit fingering of the keys of which by the little muscular performers sends through the tracheal sounding-pipe the tuneful messages of bird's highest estate. A few degraded or disgraced birds, as the ostrich and the American vultures, have no bucolic

organ at all, the trachea forking as simply as possible. Others, as the common fowl, have a fair syrinx, but no muscles whatever to modulate their pastoral lays. Others have one, two, or three pairs of intrinsic muscles; to which may or may not be added a sterno-tracheal with syringeal attachment. It is not so much the bulk or mere fleshiness of the syrinx that indicates musical ability; but the distinctness of the several muscles, and the mode of their insertion,

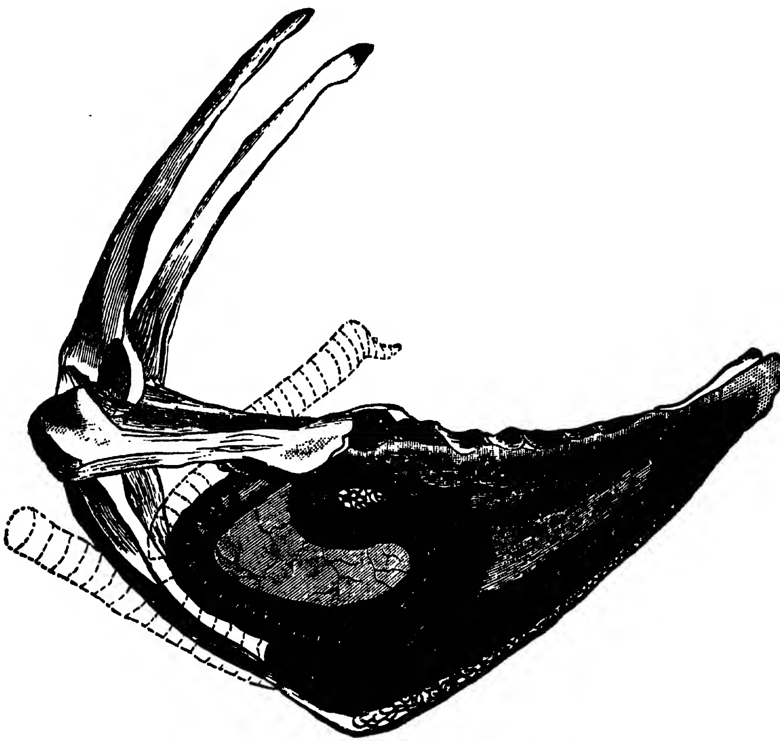


FIG. 99.—Coiling of the windpipe in the sternum of *Grus americana*; reduced.

which result in endless combinations of rotating and rocking movements of the parts, whereby an infinite modulation of the musical tones becomes possible. In *Oscines* there are normally five or six pairs of muscles, without counting the extrinsic sternotracheales; and the gist of the arrangement, in these melodious Passeres, is the attachment of the muscles to the *ends* of the upper bronchial half-rings, as far as the third one. As Professor Owen remarks with appreciative feeling, "the manifold ways in which the several parts of the complex vocal organ in *Cantores* may be affected, each of the

principal bony half-rings, as one or the other end may be pulled, being made to perform a slight rotatory motion, are incalculable; but their effects are delightfully appreciable by the rapt listener to the singularly varied kind and quality of notes trilled forth in the stillness of gloom by the nightingale."

I should be able to make the plan of the syrinx clear to the student with the assistance of Macgillivray's beautiful figures. These are drawn from the rook,—a corvine croaker, indeed, but one whose syrinx is in good order, though he has never learned to play. As the modifications affect principally the soft parts covering

FIG. 100.—Coiling of the windpipe in the sternum of *Grus canadensis*; reduced.

and moving the music-box, one description of the latter is applicable to most birds. The last lower ring, or piece composed of several fused rings, of the trachea, at its bifurcation into bronchi, is enlarged or otherwise modified (Fig. 101, [13], *aba*), and crossed below from front to back by a bony bar, the *pessulus* ([13], at *b*; [15], *a*), or bolt-bar, which, dividing it into lateral halves (as at [14]), forms thus two lateral openings instead of one median tube,—the beginnings of each bronchial tube. A membranous plate, strengthened by cartilage, rises vertically into the tracheal tube, forming a *septum*, or median partition, between the orifices of each bronchus. The free curved upper margin of this septum, extending from front to back

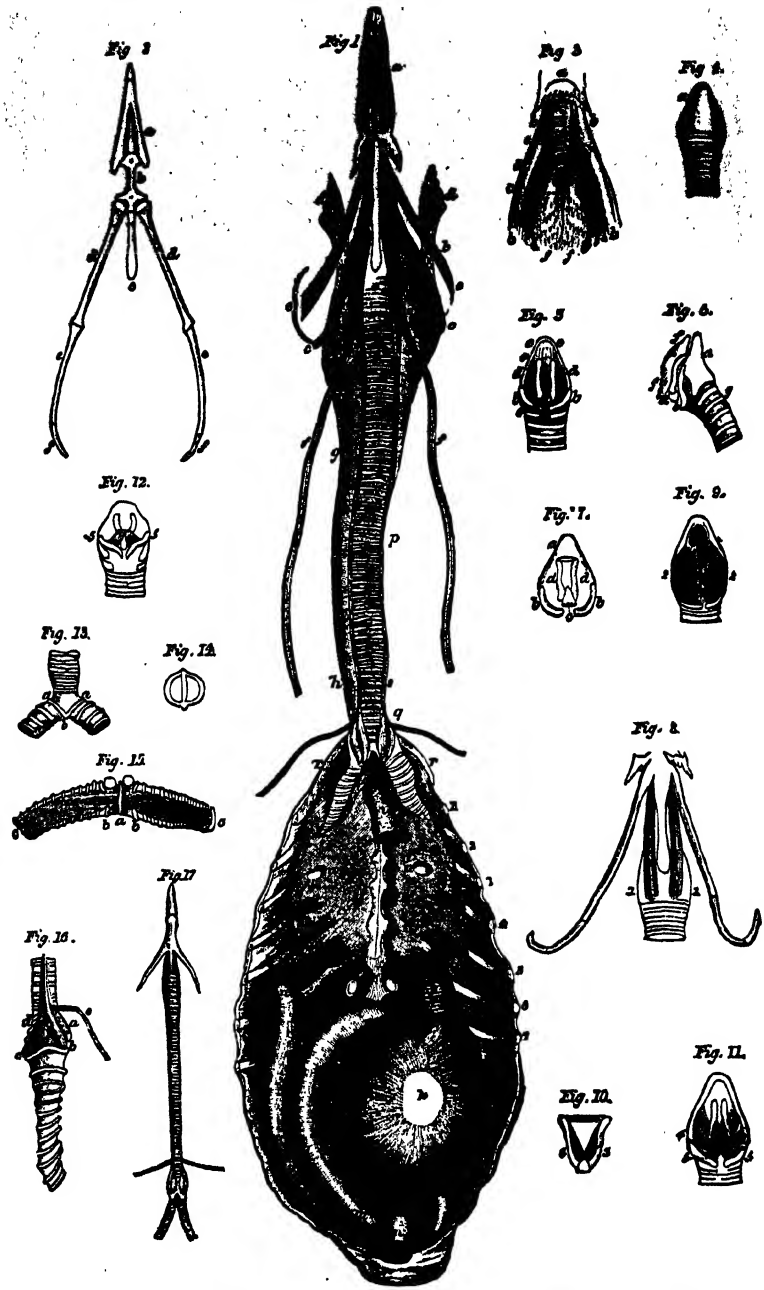


Fig. 101.—Respiratory and vocal organs of the Rook, *Corvus frugilegus*, an Oscine Passerine

bird; nat. size, after Macgillivray. 1. *a*, tongue; *b*, basibranchial, commonly called urohyal; *c*, *c*, horns of hyoid bone; *d*, *d*, geniohyoid muscles; *e*, *e*, stylohyoid muscles; *f*, *f*, cleidohyoid muscles; *g*, *h*, *i*, oesophagus; *j*, proventriculus, or secretory stomach; *k*, gizzard, or gigerium, the muscular stomach; *l*, *m*, *n*, *n*, intestine, duodenum to rectum; *o*, *p*, trachea, or windpipe; *q*, inferior larynx, or syrinx; *r*, *r*, right and left bronchus; *s*, *s*, contractor muscles of trachea; *t*, *t*, lungs, with *u*, *u*, apertures communicating with thoracic air-cells; *v*, *v*, *v*, three pairs of muscular slips answering to a rudimentary diaphragm; 1,2,3,4,5,6,7, as many ribs.—2. Hyoid bone; *a*, glossohyal, tipped with cartilage, its posterior horns being ceratohyals proper; *b*, basihyal; *c*, basibranchial proper, commonly called urohyal; *d*, *d*, ceratobranchials proper, commonly called apohyals; *e*, *e*, epibranchials proper, commonly called ceratohyals, tipped with cartilage, *f*, *f*.—3. Glottis, or opening of trachea in the mouth; *a*, base of tongue; *b*, *b*, horns of hyoid bone; *c*, rima glottidis, cleft or chink of the glottis; *d*, a triangular vacuity; *e*, an elastic ligament; *d* and *e* represent an epiglottis; *f*, *f*, a papillose surface.—4. Larynx viewed from before (below); *a*, thyroid bone or cartilage.—5. Larynx viewed from behind (above); *a*, thyroid bone; *b*, *b*, its appendages; *c*, cricoid; *d*, *d*, arytenoids; *e*, *e*, anterior border of thyroid, to which *d*, *d* are connected by two arytenoid ligaments.—6. Larynx viewed from right side; *a*, thyroid; *b*, appendage; *c*, cricoid; *d*, arytenoid; *f*, *f*, cartilage attached to arytenoid; *g*, a tracheal ring.—7. Larynx viewed from behind; *a*, thyroid; *b*, *b*, its appendages; *c*, cricoid; *d*, arytenoids.—8, 9, 10, 11, 12. Muscles of the larynx; 1, 1 (Fig. 8), thyrohyoids; 2, 2 (Fig. 9), thyroarytenoids, or openers of the glottis; 3, 3 (Fig. 10), oblique arytenoids; 4, 4 (Fig. 11), thyrocricoids; 5, 5, (Figs. 11 and 12), posterior thyrocricoids.—13. Bifurcation of trachea; *aba*, last entire tracheal ring.—14. Last entire tracheal ring, viewed from below, crossed by the pessulus.—15. Bifurcation of trachea, and bronchi, viewed from below; *a*, pessulus, the bolt-bar, or "bone of divarication"; *b*, *b*, next succeeding tracheal half-rings.—16. *a*, *b*, *c*, *d*, inferior laryngeal or syringeal muscles, not well made out in this figure; see text. But the typical oscine arrangement (acromyodian) is perceived, inasmuch as anterior (*a*) and posterior (*d*) intrinsic muscular masses go to *ends* of the first tracheal half-ring, at *b* and *c*; the extrinsic slip *e* passing to sternum; compare Fig. 1 at *q*.—17. Trachea, etc., of the nightingale, nat. size. (Compare Figs. 3, 67, 72, 73, 74.)

of the orifice, is called the *semilunar membrane;* being the edge of a partition common to both bronchi, it forms, in fact, the *inner lip* of each bronchial orifice; that is to say, the inner *rima glottidis syringis*, or lip of the syringeal mouthpiece. This membrane vibrates with the column of air, and is, in fact, one of the "vocal chords." Now the bronchial rings which succeed are not annular, circumscribing the bronchial tube, but are half-rings ([15], *b*, *b*), or arcs of circles to be completed by membrane, which forms more or less (scarcely or not half) of the circumference of the tube; this membranous part, termed the *internal tympaniform membrane* ([15], *c* to *c*), being on the side of the bronchus which faces its fellow, while the hard bronchial half-rings complete the rest of the cylinder. The membrane is attached to the pessulus above. This accounts for the whole bronchial tube and its vocal septum from its fellow. Now the concavity of the upper two or three bronchial half-rings, on the outer wall of the tube, but in its interior, is the place where is developed a certain fold of the mucous membrane, projecting into the tube opposite the septum, and forming the outer lip of the syringeal glottis; for this membranous fold, like the semilunar membrane, is set quivering in vocalisation. The upper tracheal rings which enter into this arrangement are enlarged and otherwise modified. Thus are formed two "vocal chords," upon the vibrations of which the harmonious or discordant notes of the bird depend. The chords are struck by the hand of air indeed, but endless musical variations result from the play of the muscles in increasing or diminishing and variously combining the tension of the several parts of the instrument. In giving four pairs of intrinsic syringeal

muscles (anterior external, anterior internal, intermediate, and posterior, besides the extrinsic sternotracheales), as figured in [16], *a*, *b*, *c*, *d*, and *e*, Macgillivray is said to have understated the full oscine number, which is five or six. In the raven, Owen describes *five*, without counting the sternotrachealis: *bronchotrachealis anticus*, anterior external; *bronchotrachealis posticus*, posterior external; *bronchotrachealis brevis*, posterior internal; *bronchialis anticus*, anterior internal; and *bronchialis posticus*. The general arrangement, however, is fairly indicated by Macgillivray in [16], where on the side of the syrinx, the muscles are seen to diverge from the tracheal lateral line to go to *ends* of the bronchial semi-rings.

The student will understand that my description is particular only as regards the oscine syrinx; that in birds at large every possible modification, almost, of lower tracheal and upper bronchial rings occurs, and with various musculation, or with none. The non-oscine rule for the muscles is, one on each side, if any; and insertion into mid-parts, not ends, of the bronchial half-rings. The latter character chiefly distinguishes the non-oscine syrinx when it has several muscles. As to situations of the syrinx, three have been recognised: the ordinary *bronchotracheal*, in formation of which both bronchi and trachea take part; the *tracheal*, only known to occur in some American Passeres, as in *Thamnophilus* and *Opetiorhynchus*, situated wholly in the trachea, the lower part of which is extensively membranous; and the *bronchial*, wholly in the bronchi, as in *Crotophaga* and *Steatornis*.

The Song of Birds unlocks the great secret of Genesis to those who can hear the keynote. It is the closest approach in animate nature to the ringing of the hydrogen bells in the physics of light. The musical instrument figured (101, [17]) is the identical pipe the "great god Pan" first fashioned for a legacy to all time, as so sweetly said by Mrs. Browning:—

. . . . .

"He tore out a reed, the great god Pan,
From the deep cool bed of the river.
The limpid water turbidly ran,
And the broken lilies a-dying lay,
And the dragon-fly had fled away,
Ere he brought it out of the river.

. . . . . .

"'This is the way,' laughed the great god Pan,
(Laughed while he sate by the river!)
The only way since gods began
To make sweet music, they could succeed.'
Then dropping his mouth to a hole in the reed,
He blew in power by the river.

"Sweet, sweet, sweet, O Pan,
Piercing sweet by the river!
Blinding sweet, O great good Pan!
The sun on the hill forgot to die,
And the lilies revived, and the dragon-fly
Came back to dream on the river."

But the sad sequel, felt by Keats, when poor Psyche has seen and known, and Eros has found his wings—

"So did he feel who pulled the boughs aside,
That we might look into a forest wide,
To catch a glimpse of Fauns and Dryades
Coming with softest rustle through the trees;
And garlands woven of flowers wild and sweet,
Upheld on ivory wrists, or sporting feet;
Telling us how fair trembling *Syrinx* fled
Arcadian Pan, with such a fearful dread.
Poor Nymph,—poor Pan,—how he did weep to find
Naught but a lovely sighing of the wind
Along the reedy stream! a half-heard strain
Full of sweet desolation, balmy pain."

The blessed bluebird, "bearing the sky upon her back," is burthened with the same "light load of song"—

Have you listened to the carol of the bluebird in the spring?
Has her gush of molten melody been not poured forth in vain?
Ah! then the pulse has quickened, and a sigh, perhaps, has risen,
From the breast the bluebird's music stirs to thoughts that lack expression—
So tender, so tumultuous are the fancies thus aroused.
The bluebird's song breathes gladness—breathes the sweet and solemn triumph
Love feels when all love's passion melts in its own fruition.
Exquisitely subtile are the chords the bluebird touches—
Chords that quiver now in ecstasy, now thrill in fond expectancy,
Now die in dreams of all that might have been.
Hers is language to interpret, and translate in accents rhythmic,
All the yearning of young love to claim his own—
Of young love that trembles on the threshold of the passions,
And shrinks before the images his ardour calls to life.
Thus to the maiden musing come thronging thoughts unbidden,
When she hears this speaking echo of the hopes that glow within;
And the tell-tale blushes redden to the rose-tint on the bosom
Of the bird that dares to breathe her secret joy.
Thus to the youth impetuous, whose life is set to music—
Let love but laugh and beckon from afar—
Fulfilment sends a greeting in the soft voluptuous languor
That steals upon the senses if the bluebird's song be heard—

This song of wondrous gladness, ever bubbling, welling, gushing,
From a fountain full of promise, inexhaustible, divine!
Sweeter far these liquid accents when the buds of hope are blighted,
And the tree of knowledge bears its bitter fruit;
When memory sits brooding on the ashes of her birthright,
And sackcloth shrouds a heart that once was young;
For a silver chord is quickened where was greedy, silent sorrow—
Responding to a sympathetic touch:
The bird sings true and tender, with a precious burden laden,
With the tidings of a love that never dies.
So in the timid spring-time, when the world wears wreaths of roses,
Ring clear the joyous melodies of hope!
So in the summer season, when the wine of pleasure reddens,
Ring passionate the triumphs of the heart!
So in the sad, still autumn, when life bends beneath its burden,
When what might have been has never come to pass,
Rings once again this music on the crushed and wounded spirit,
Bringing light where all was dark and drear before:
All is not lost if the music that the bluebird bears be heeded,
For her mission is to tell us love is God.

Though it is a fact that "the *Chenomorphæ* are not provided with intrinsic syringeal muscles," there may be much truth in treatises *de cantu Cycni morituri* which have appeared from time to time, and to the number of which I may be pardoned for adding—

How sadly sweet, how soft and low
    Is the music born of pain—
How mournful sounds the ebb and flow,
What measured beats, what throb and throe,
    In the wild swan's dying strain!

The archer, Death, and the twanging bow,
    And the fateful shaft on-sped,
All state and grace and pride laid low,
Disordered plumes and crimson flow—
    For the white swan's heart has bled.

But hear the mournful cry that rings
    On the startled air of night!
As a spirit form in the darkness wings
Its way unseen, the wild swan sings
    His psalm of life and light.

How sadly sweet the solemn strain—
    The dirge of the dying swan!
That wondrous music, child of pain,
That requiem, sounding once again—
    And a bird's soul passes on.

f. Splanchnology: the Digestive System.

The Alimentary Canal, or digestive tract, is a tube which passes through the body from mouth to anus, conveying food, the nutritious qualities of which are drawn off by the lacteals *in transitu* and assimilated, the refuse being voided. This is *digestion*. The canal is really a tube within a tube, being contained in the cavity below the bodies of the vertebræ, formed by the series of *hæmal arches*. Birds are very fast livers, their digestive operations, like the processes of respiration and circulation, being very active and effectual; they require proportionally greater quantities of food. The voracity of the cormorant is proverbial, but it is probably not greater than that of the ethereal nightingale. Birds as a class are omnivorous; many species are as nearly omnivorous as any animals can well be; but the majority are either vegetarian or flesh-feeding. Very many birds feed upon fruits, hard or soft; but even these, when in the nest, are nourished for the most part upon the bodies of insects; and it may be truly said that the great majority of birds are insectivorous. Birds seem to be the great controlling agency in the economy of nature of the increase of insect life; agriculture would be difficult if not impracticable without them, and their economic value is simply incalculable. Insectivorous birds cannot be much interfered with, without destroying one of the most important and consequential of nature's many beautiful adjustments. The bird cries perpetual "échec!" to the insect. Even those birds which are mainly flesh-eaters, as the hawks and owls, are similarly beneficial, for the creatures they chiefly prey upon are the small rodents so hateful to husbandry. The carrion-eaters contribute largely to make tropical regions habitable to man. Various tribes of birds feed almost exclusively upon fish; and these sometimes reach the dignity of diplomatic and other political interests of mankind: nations have gone to war over the dung of such birds, guano-beds being to some of the South American powers a large item of their revenue. Chili and Peru have been fighting lately, and the United States have been wrangling over the excrements of the alimentary canal of sea-birds. This tube in general is shortest, simplest, and most direct in the flesh- and fish-eaters, the nature of whose food assimilates already more nearly to the substance of their bodies than does that of the vegetarians. The tube is modified in different portions of its extent for the prehension, retention, saturation, maceration, and comminution of food, and the mixture with it of other solvent fluids than those secreted by the mucous membrane of the alimentary canal itself. Hence arise the various modifications of its length, dilatation here, contraction there; the presence in its lining membrane of numerous follicles; and the annexation of various glandular organs.

Being always longer than the body, the tube is necessarily coiled away in certain places; this folding taking place chiefly in the intestinal part of the tract. Modifications of structure make recognisable parts, as the mouth, gullet, crop, stomach, gizzard, intestine, cloaca, anus. Annex organs are the salivary glands, the liver, and the pancreas, all of which pour their secretions into the canal. This tube also receives the terminations of other systems of organs: the auditory organ of special sense; the respiratory system, which is at first a mere bud or offset from the digestive; the urinary and the generative, which, though originally distinct, primitively and permanently open into the lower bowel. The intestine is also continuous with the cavity of the umbilical vesicle of the embryo, a primitive structure which disappears as the chick matures; and with that of the allantois, another embryotic organ which begins by budding from the intestinal cavity. Its connection with the system of blood-vessels is direct through the lacteals and thoracic ducts (p. 295). Its operations are automatic and spontaneous, of the "reflex" order; that is, excited by the presence of food,—having *work to do making it work*, so to speak. Its innervation is chiefly by the pneumogastric and sympathetic nerves; and digestion is the most purely vegetative function, dealing with the raw materials of nutrition and consequently of the growth and repair of the whole body. The active factors in this transaction are several species or varieties of small creatures, called *Enteramœbæ;* they are all derived by descent with modification from the hypoblastic cells of the early embryo. Those of the canal itself form all the mucous epithelium of that structure, with its various secretory crypts, follicles, and villi; similar creatures, perhaps of different genera, form the lining of the salivary, hepatic, and pancreatic glands. Blood-vessels in intimate connection with the digestive organs form that special venous arrangement by which the blood coming from that part of the intestinal tract where chyle is made is collected in a *portal* system and sent through the liver,—in the embryo a sort of "great dismal swamp" which interrupts the ordinary current. The tube within the tube is fixed not only at its ends, but by various membranous connections, among them the *mesenteries.* We will notice the several departments of the alimentary canal and its annexes; reference should be made to Fig. 101, where most parts of the digestive system are shown.

The Mouth and Tongue.—The most anterior of the special cavities into which the tube is divided, and the "manual" organ it contains. The mouth in general corresponds to the shape of the jaws, already sufficiently noted. The anterior part is much hardened, like the beak; in fact, this hardness of the buccal cavity, and the absence or very slight distinction of a "soft palate,"

are among the peculiarities of a bird's mouth. There is consequently little distinction, if any, between mouth proper and *fauces*, or *pharynx*, which is the posterior part, leading directly into the gullet. Besides this communication, the mouth receives the terminations of four special cavities. 1. The *posterior nares*, on the roof of the mouth posteriorly, generally a median slit leading into the nasal chambers. 2. The generally single and median and more posterior opening of the *Eustachian tubes*, which lead into the tympanum, and are the remains of the first postoral visceral cleft of the early embryo. 3. The *glottis* (Fig. 101, [3], *c*), a slit at the base of the tongue, the opening of the windpipe, and so of the whole respiratory system, which is defended by a rudimentary trap-door, the *epiglottis*, if any. 4. One or several pairs of orifices, the openings of the ducts of the *salivary glands*. These structures, corresponding to the parotid, submaxillary, and sublingual glands of mammals, vary extremely in their development. In woodpeckers, for example, and some *Raptores*, elaborate special salivary glands occur, having a glomerate structure and a special *duct of Stenson*. In many other birds, similarly compound but less elaborate submaxillary glands pour their secretion into the mouth by a series of pores. In most birds, however, the salivary glands are small, simple, and less distinct from various other sets of mucous crypts which open into the mouth. In the great bustard (*Otis tarda;* Fig. 102) there is a singular buccal structure; a great pouch opening beneath the tongue, susceptible of distension during those amatory antics termed the "showing-off" of the creature. It is in fact an air-sac, but not of the kind already considered (p. 296), having no connection with the respiratory system. The narial, Eustachian, and glottidean apertures are commonly defended by retrorse papillæ; and other such processes of mucous membrane, knobbed or acute, may occur elsewhere in lines and patches. The roof of the mouth is nearly all "hard palate," as already said; its soft floor is the mucous membrane and skin between the forks of the under jaw, with muscular or other intervening structures. The principal flooring muscle is the *mylohyoid;*

FIG. 102. — Gular pouch of bustard; copied by Shufeldt from Garrod. *a*, tongue; *b*, the pouch, opening under *a*, hanging in front of *c*, the trachea, behind which is the œsophagus, *d*, with its crop, *e*.

the *geniohyoid* (Fig. 101, [1], *d*) is another, which passes like the first from the mandibular to the hyoid bone; a third is the *stylohyoid* (*e*). The floor in some cases forms a pouch, which, as in the pelican, is of great extent and susceptible of enormous dilatation.

The handler of the mouth, or lingual organ, is the tongue, which answers the same purpose as in other creatures: it is tactile, to some extent gustatory, sometimes prehensile, nearly always manipulatory. In some birds, as the pelican and ibis, and also the kingfisher, it is very slightly developed,—scarcely more than a pad at the bottom of the mouth, enjoying the most limited motion or other function. In some birds, as the parrot and duck tribes, and also the flamingo, the tongue is large, thick, and fleshy, quite filling the mouth. In the first-named of these, it is dexterously manipulatory; the morsel of food is managed between the tongue and upper beak; the tactile certainly, and perhaps the gustatory sense is highly developed; and the fleshiness of the tongue may affect that power of articulate speech for which some parrots are justly noted. In the *Lamellirostres* just mentioned the tongue has lateral processes corresponding to the denticulations of the beak, and the under surface is horny at the end, like a human finger-nail. In the woodpeckers (Figs. 73, 74) the tongue itself (glossohyal part of the hyoid) is reduced to a slight horny and spiny tip of the lingual apparatus; but other parts of that mechanism are so extraordinarily developed that the "tongue" appears as a *lumbriciform* (worm-like), spear-headed organ usually capable of great protrusion from the mouth, and therefore acting as a prehensile instrument, being bedewed for that purpose with tenacious saliva from the great salivary glands; while it is actuated in protrusion and retraction by specially developed muscles. In the snipe and many other long slender-billed waders, the tongue is similarly slender, but not protrusible. The long narrow tongue of the toucans (*Rhamphastidæ*) is beset with slender processes, so that it seems feathery. The tongue of the humming-bird is very singular. These and other interesting extremes aside, the ordinary style of a bird's tongue is flat, narrow, more or less sagittate or lanceolate, and tipped or sheathed in horn, commonly with lateral backward processes like the barbs of an arrow-head,—the whole *glossal* structure upborne pretty distinctly upon the end of the basihyal bone. (See Fig. 101, where [1], *a*, is such an ordinary tongue, and [2], *a-f*, is its whole skeleton.) Such horny tongues are commonly bifid at the extreme tip or there variously lacerate, or laciniate, or thready,—and even the fleshy tongue of some parrots, as the lories, is brushy at the end. The bony foundation of the tongue is the composite hyoid bone, already often mentioned; the free lingual part proper is based upon the glossohyal and its terminal cartilage; the roots curve more or less extensively about the base or more of the skull.

The tongue is moved by some intrinsic muscles, as well as by those extrinsic ones by which it is connected to the skull, jaw, and windpipe (Fig. 101, [1] and [8]).

The Œsophagus.—After comminution, if any, by the beak, and insalivation in the mouth, food passes directly through the pharynx into the *œsophagus* or gullet,—a musculomembranous tube connecting mouth with stomach (Fig. 101, [1], *g*, *h*, *i*). This is composed (besides its mucous membrane) of circularly disposed *constrictor* fibres, and longitudinal *contractor* fibres, of *Myamœba*, of the pale, smooth species (*M. lœvis*). It has generally a pretty straight course, but may be diverted to one side or the other; and, in particular, is subject to various dilatations and contractions, permanent or temporary, aside from the mere distension caused by the passage of food. When the floor of the mouth is wide and loose, the gullet partakes of the same character above; the extreme case is afforded by the pelicans, especially *Pelecanus fuscus.* But the gullet of many small birds, as various genera of *Fringillidœ* and *Corvidœ,* is much more distensible than is commonly supposed, and may be found crammed with seeds which there find resting-place for some time. The fish-eating birds, as herons, cormorants, loons, and others, have also capacious gullets. The Australian bustard, *Eupodotis australis,* has an œsophagus capable of such extraordinary distension that it hangs down in front of the breast when inflated with air, as it is in the amatory display in which that species is wont to indulge. Aside from mere distensibility of transient character, the œsophagus of many birds becomes modified anatomically into a special pouch, —the crop or craw, *ingluvies,* where the food is detained to be macerated in a special secretion before passing on to the true stomach. Such definite crops occur in birds of prey, which gorge such masses of food in their irregular voracious banquets that it cannot all be received into the stomach at once; and likewise throughout the orders of Columbine and Gallinaceous birds, which habitually feed upon seeds and other fruits so hard that they are advantageously macerated as a preliminary to true digestion. The common fowl furnishes a good illustration of a large, definite, single and median crop; in pigeons it is a pair of lateral dilatations. In these latter birds, when they are rearing their young, the secretion of the ingluvies, always copious, becomes still more so, and of a milky character in consequence of the activity of the altered mucous surface; it is regurgitated into the mouths of the young along with the macerated grains. "This phenomenon is the nearest approach in the class of Birds to the characteristic mammary function of a higher class; and the analogy of the 'pigeon's milk' to the lacteal secretion of the Mammalia has not escaped popular notice." Various other birds also feed their young by regurgitation of elaborated

food; and very many similarly reject indigestible portions of their ingesta. Such vomiting is best known to be the wont of birds of prey, which habitually throw up the hair, feathers, and bones of their victims, made up into the boluses called "castings"; but the practice is far from being confined to these flesh-eaters. The extreme case of emesis offered by birds is witnessed in the hornbills (*Bucerotidæ*) which have been known to throw up the coat of their stomach without discomfort,—what a blessing it would be to some old topers if they could do the same and grow another with equal ease! In fact, in consequence of the capacity and directness of the gullet, vomiting is very easy to birds, and with some it is a means of self-defence,—very effectual, for instance, in the cases of American vultures (*Cathartides*). Fish-eating birds, as herons, gulls, petrels, habitually vomit when wounded or otherwise molested.

The Proventriculus.—The tube just considered ends below in a special tract, variously dilated or not, but always peculiar in the presence of certain gastric follicles which secrete the digestive fluid proper. The "stomach" of a bird, in fact, is compound, consisting of a glandular or digestive portion, and a muscular or grinding part. The former is the *proventriculus;* whatever its size or shape, or whatever its magnitude in comparison with the grist-mill, it is recognised by the presence in its mucous surface of these gastric follicles, secreting the peptic fluid which *chymifies* the food. The follicles are perhaps always large enough for this part of the tube to be recognised by the naked eye,—the mucous membrane having here a thickened, velvety, vascular appearance. The glands are of various sizes and shapes,—usually simply tubular, sometimes clubbed or conical, or variously racemose (like a bunch of grapes). They are disposed in a zone around the tube, or in patches upon part of its surface,—in the darter (*Plotus*), very singularly in a separate lateral compartment looking like a crop. Details of the grouping of these solvent glands are interminable. Whatever its anatomical variations, and however like the end of the œsophagus it may simply appear to be, this *ventriculus glandulosus* is the bird's proper stomach (Fig. 101, ^{1}, *j*).

The Gizzard.—Mixed with the salivary, ingluvial, proventricular and other secretions of the mucous surface, and already chymified, the food of birds next passes directly into the gizzard, *gigerium*, or muscular division of the stomach, sometimes called the *ventriculus bulbosus*. The two are sometimes separated by a tract, sometimes immediately consequent. In the muscular gizzard, the food-grist is ground fine. To this end, the walls of the cavity become developed into a more or less powerful muscular apparatus, and the mucous membrane changes to a tough, thick, horny, occasionally even bony, lining; this callous cuticular lining being often

very loosely attached, and even deciduous in some cases. The muscular arrangement is chiefly in two great masses, called the *lateral muscles*, converging to a central tendon; between them intermediate fibres may form a more or less distinct muscular belly. In the most powerful gizzards, the muscular tissue is very dense and dark coloured, the tendons brilliantly glistening, and the contained "millstones" extremely callous. Such a gizzard is well displayed by the common fowl or the goose. The opposite extreme is afforded by the carnivorous and especially the piscivorous birds, whose soft food requires little trituration,—it is all a matter of degree. How readily this part of the canal responds to the regimen of the bird is witnessed in the cock-of-the-plains (*Centrocercus urophasianus*)—a bird whose gizzard is so slightly muscular as to appear like a membranous bag, though its gallinaceous relatives have extremely strong grinders. Its food is chiefly the buds and leaves of the wild sage (*Artemisia*) and grasshoppers. Increased muscularity of the gizzard has even been artificially produced. Birds whose grist is heavy habitually swallow gravel, that these small stones may mechanically aid in the grinding process. The action is so energetic, that in auscultating a fowl when the mill is in full blast, the noise of the grinding can be distinctly heard. The pebbles, in fact, have a function which leaves "hens' teeth" not merely mythical. The kind of motion impressed upon the opposing pads of cuticle is alternating,—a rubbing back and forth to a slight extent. Peculiar dispositions of the callous surfaces are found in some pigeons, with corresponding peculiarity of the cross-section of the gizzard. In some of the cuckoos a matting of impacted hairs of lepidopterous insects has been mistaken for a coat of the gizzard itself. In the darter, which has a pyloric division or compartment of the gizzard, this is nearly filled with a mass of matted hairs, a peculiar modification of the epithelial lining, serving to guard the pyloric orifice. Folds of the lining membrane form a pyloric valve in many birds. The *pylorus*, or the *pyloric* orifice, is that opening by which food leaves the gizzard for the intestines; the orifice of entrance from the œsophagus is the *cardiac*. The two are always near together, and sometimes adjoining. (In Fig. 101, ^{1}, *k* is on the central tendon of the moderately muscular gizzard; the cardiac orifice is between *j* and *k*, and pylorus between *l* and *k*.)

The Intestine continues the alimentary canal to the cloaca. Any difference in the length of the whole tract, relatively to that of the bird, is chiefly produced by the foldings of the intestine, especially in the upper portion of its course. The extremes of proportionate length are perhaps not ascertained; but known to be from less than 2 : 1 to more than 8 : 1. In birds there is little or no distinction between "small" and "large" intestine as to the

calibre of the tube, nor is the latter sacculated as in mammals. The former is considered to extend from the pylorus to the *cæca* (structures to be presently noticed). Above the cæca the intestine commonly receives its foldings and windings; below them it usually proceeds more directly, or quite straight, to the cloaca, forming literally a "rectum"; but in the ostrich this ultra-cæcal tract is longer than the rest, and convoluted. The cis-cæcal portion is conventionally divided into *duodenum*, *jejunum*, and *ileum;* there is, however, no positive anatomical distinction of these parts in any animal with which I am acquainted. In birds, a "duodenum" is perhaps as distinct as ever; it forms the most constant duplication of the intestine, the pancreas being lodged in this *duodenal fold* (Fig. 101, [1], *l*, *m*, *n*). The course of the intestine is otherwise very various in different birds. The upper end, near the pylorus, receives the hepatic and pancreatic ducts; and food is *chylified* after impregnation with the biliary and pancreatic fluids; a process furthered by the proper secretions of the intestinal follicles. The *chyle* is drawn off by the *lacteals* already described (p. 295), and the unassimilable refuse of the food becomes excrementitious.

Cæca (Lat. *cæcus*, blind, in the nom. pl. *cæca;* sing. *cæcum*).—The "blind guts," so called because they end in *culs-de-sac*, are of two kinds. One is the *umbilical cæcum*, or *vitelline cæcum*, a rudimentary, or rather vestigial, structure, the remains of the open duct by which the cavity of the umbilical vesicle (an embryonic organ) communicated with that of the intestinal tract. It is ordinarily not to be noted at all; but it is said by Owen to have been found half an inch long in the gallinule, an inch in the bay ibis, and dilated into a sac an inch in diameter in the *Apteryx*. The structures ordinarily called *cæca*, or *cæca coli*, for they are usually paired, are pouches or diverticula which set off from the intestine proper at the junction of the ileum with the colon; but there is nothing in the intestine itself to mark this point, so that when cæca are absent, as frequently happens, no distinction of ileum from colon or rectum is appreciable. No other part of the intestinal tract is so variable as the cæcal: so that presence or absence of these appendages furnishes zoological characters nowadays taken very commonly into account in framing genera and families. There are no cæca, as in the turkey-buzzard and some pigeons; there is a single small cæcum in herons. From a condition of extremely small size, like little buds upon the intestine, cæca are found to elongate to extraordinary dimensions; and the large specimens are frequently saccate or clubbed, with slender roots. In geese and swans the cæca are a foot long, more or less; in some grouse they are said to be a yard long. In the ostrich the mucous membrane is thrown into a spiral fold. However developed, the physiology

of these intestinal appendages is the detention of food until all its nutritive qualities are absorbed, and increase of the absorbent surface.

The Cloa'ca (Fig. 101, [1], *k*) or "sewer," very well named, is the termination of the bowel,—an oval or globular enlargement of the rectum, of sufficient capacity at least to contain the completely shelled egg. For, not as in placental mammals, the urogenital and digestive organs are behindhand in their evolution, and do not entirely lose connection with each other. Nor is there in birds any distinct bladder; but a cavity, originally that of the allantois of the embryo, persists in common with that of the intestines, and is the *cloaca*. Such incomplete distinction between the two as there may be, by a folding of mucous membrane or partial compartment of the whole, results in cloaca proper, and *urogenital sinus*, in which latter are the papillose orifices of the *ureters*, one on each side, from the kidneys; and of the single oviduct (♀) or paired sperm-ducts (♂), from ovary or testes. The urine of birds not being liquid requires no more of a bladder than this sinus furnishes. The same cavity contains the penis of those birds, as the ostrich and drake, which are provided with an organ of copulation. A peculiar anal gland, the *bursa Fabricii*, also opens into the cloaca. Refuse of digestion, the renal excretion, the spermatic secretion, and the product of conception, are discharged by a single anal orifice, the two former *en masse*.

Being intimately related to dietetic regimen, and so to the habits of birds, the alimentary canal varies greatly,—even more than my slight sketch shows,—and consequently affords good zoological characters in the details of its construction. But of all the anatomical systems, this is the one most variable as a matter of *physiological adaptation* (see p. 103). Its characters, even when they seem weighty, are therefore peculiarly liable to be fallacious as indices of natural affinities, and must be applied with discreet caution to morphological classification. Such are commonly only of generic significance. Thus in pigeons the cæca and even the gall-bladder may be present or absent in neighbouring genera.

Alimentary Annexes.—Some of these, as the salivary glands, have been noticed already. The two most important bodies connected with the digestive tract, and properly considered adjuncts, are the pancreas and the liver. The former is that kind of lobulated salivary gland which in mammals is called the "sweet-bread." It lies in the duodenal loop, along which its loosely aggregated lobes extend. Its ducts, formed by the successive union of smaller efferent tubes, are two or three in number; they pierce the intestine a little below its commencement at the pylorus, and pour into the canal the pancreatic juice, which has the property of

emulsionising fat. The *liver* is a well-known glandular organ of very special structure and function, secreting the fluid called *bile*, also received into the intestine. It is of moderate size in birds, and deeply divided into two principal (right and left) lobes: in some birds there is also a smaller lobe; and one of the large lobes may also be divided. The lobes dispart above to receive between them the apex of the heart; they are held in place by pleuro-peritoneal folds contributing to form the thoracic-abdominal air-cells. This viscus receives venous blood from the extensive portal system; two hepatic veins then conduct it to the post-caval. The emunctory ducts, carrying off the bile, are two or three in number. One at least goes directly to the intestine, and another to the gall-bladder, when that cyst exists; in which case there is a separate cystic duct from the bladder to the intestine, no *ductus communis choledochus*, or duct common to the hepatic substance and its cyst, being formed in birds. Two hepatic ducts may coexist with a cystic duct, making three to the intestine, all separate; two is the rule when there is no gall-bladder. These emunctories commonly enter the intestine some distance apart, and beyond the pancreatic ducts. The gall-bladder is generally present, sometimes absent; it may occur or not in closely related genera of birds.

g. Oölogy: the Urogenital Organs

The Urinary and Generative Organs may be conveniently considered together, not only on account of their close anatomical relations, but because their physiological functions, totally diverse in adult life, are primitively related in the most intimate manner. For it is a singular fact that the mean office of straining urine out of the system is at first sustained by a structure (Wolffian body), in closest connection with which, in the female, actually as a part of which, in the male, are later developed those organs (ovary and testis) whose exalted office is creative; for these permanent genital glands procreate the microscopic creatures called *Dynamamœbæ*, the marriage of which results in the reproduction of a complex organism like the male or female parent. (See Figs. 103, 104, and following.)

The Wolffian Bodies, or *primordial kidneys*, are a pair of tubular structures which appear very early in the progress of development of the embryo, beneath the spinal column, in front of the fore end of the future kidneys; with each of them is developed a duct, the *Wolffian duct*, which carries their excretion into the cavity of the allantois (the future cloaca). Upon the appearance of the true kidneys, the transitory Wolffian bodies and ducts lose their urinary function; they ultimately disappear from the female, for the most

part, leaving only a trace of their former existence in certain vestigial structures (*parovaria*, etc.); in the male, likewise, they atrophy, but not to the same extent; for a portion of the bodies persists as an accessory (epididymal) portion of the testicle, and their ducts persist as the sperm-ducts, or *vasa deferentia.* Meanwhile, in closest connection with the Wolffian bodies, appears a pair of organs, the *genital glands*, for a while exactly alike. If the new creature is to become *female*, the *genital gland* develops to a certain complexity of tissue and becomes the *ovary;* while a certain duct, the *Müllerian duct*, developed coincidently to connect such ovary with the cloaca, becomes the *oviduct.* In birds usually only one ovary and oviduct (the left) becomes functional. If the new creature is to become *male*, the same *genital gland* develops to a higher degree of complexity, acquires a tubular structure, and becomes the *testicle;* it connects with remains of the Wolffian body, and the Wolffian duct becomes the permanent sperm-duct, conveying the product of the male function to the cloaca, just as the oviduct conveys the product of the female function to the same sewerage. Thus the testicle of the male and the ovary of the female are homologous, in fact primitively identical organs, upon which sexual difference is impressed by the greater complexity of structure acquired if the sex is to be male; a female being, anatomically and physiologically, simply an imperfect male, arrested at one stage of her physical progress to male perfection of structure; and the whole nature of the female bears out the same relation of inferiority. But the oviduct of the female and the sperm-duct of the male, though physiologically identical, having the same function of conveying the products of generation from the genital gland to the light of day, are not anatomically the same; for in the case of the female, whose Wolffian duct has disappeared, the Müllerian is the oviduct; in the case of the male, in which no Müllerian duct appears, the Wolffian is the sperm-duct. The two are analogous, not homologous (a good illustration—see page 103). But it must be further observed that while the sperm-duct conveys only the masculine essence from centre to periphery, the oviduct conveys the feminine material from centre to periphery, and *also* the male essence in the opposite direction; for upon coitus, which is direct in all birds, the spermatozoa deposited in the cloaca of the female find their way up through her oviduct to the ovary, there to accomplish impregnation of the ovarian ova, the fecund product then passing down by the same avenue. All that relates to the mysteries of generation—both the structure and function of the reproductive organs, and the maturation of the product of conception, is properly *Oölogy* (Gr. ᾠόν, *oon*, an egg); though the term is vulgarly used to signify merely a description of the chalky substance in which the egg of a bird is

finally invested. The anatomy of the egg is *Embryology*. An egg, or *ovum*, is simply the product of conception up to the time that product acquires an independent existence; while still connected with the female tissue of the ovary, and before or after it amalgamates with the male element, it is an *ovarian ovum;* more or less incompletely matured, it is an *embryo* or *fœtus*—the former term being commonly applied to the unhatched young of birds. The only difference between the "egg" of a "viviparous" mammal and

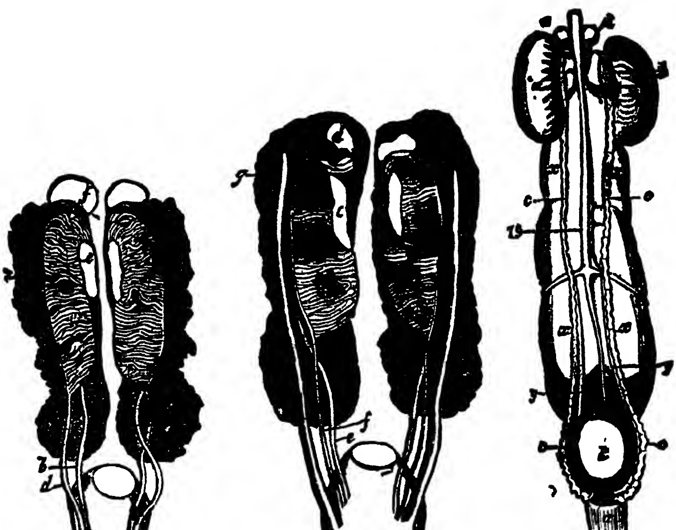


FIG. 103. — Urogenital organs of male embryo bird; from Owen, after Muller. *a*, kidneys; *b*, ureters; *c*, Wolffian bodies; *d*, their ducts, to become sperm-ducts; *e*, genital glands, to become testicles; *f*, adrenals.

FIG. 104.—Urogenital organs of female embryo bird; from Owen, after Muller. *a*, kidneys; *b*, Wolffian bodies; *c*, genital gland, to become ovary; *d*, adrenals; *e*, ureters; *f*, Wolffian ducts, to disappear; *g*, Mullerian ducts, to become oviducts.

FIG. 105.—Urogenital organs of the domestic cock; after Owen. *a*, testis; *b*, epididymis; *c*, sperm-duct or vas deferens; *d*, adrenal; *k*, cloaca; *x*, kidney; *y*, ureter.

that of an "oviparous" bird is in the albuminous and cretaceous envelopes of the latter, and its speedy expulsion from the body of the female to be hatched outside, without anatomical connection with the mother after the hard shell is formed; whereas in most mammals the ovum is retained in a dilated part of the Müllerian duct (uterus or womb) until it "hatches"; but mammal and bird alike "lay eggs," the essential germinative part of which is identical. Appreciation of these facts, and a proper idea of the relations of the mature sexual organs to the Wolffian bodies, is necessary to any understanding of the parts and processes concerned in repro-

duction.[1] We have here to consider the permanent as distinguished from the transitory kidneys, and may then recur to the subject of generation.

The Kidneys (Lat. *renes*, Engl. *reins*, adj. *renal;* Figs. 103, 104, *a;* 105, *x*) differ much from those of mammals in physical characters, though identical in function—that of straining off from the blood certain deleterious substances in the form of urea; whence they are sometimes called *emulgent* organs. Their office of purification is analogous to that of the lungs, which decarbonise the blood, and to some extent vicarious, as is that of excretory organs in general. As the lungs are closely bound down to the thoracic region of the trunk, so are the kidneys impacted in the pelvic region, being moulded to the many sacral inequalities of surface. They are paired, but sometimes connected across the median line by renal tissue; they have no special renal artery, but derive their blood from various sources; and blood from them takes part in the hepatic portal system, no reniportal being accomplished. They have little or nothing of the particular mammalian configuration which has made "kidney-shaped" a common descriptive term; being elongated, somewhat parallel-sided, and rectangular, flattened bodies, lobated into a few large compartments, and lobulated into many lesser divisions; their figure depends much upon that of the pelvis. They are very dark coloured, rather soft, easily lacerable, and appear to the naked eye to be of a granular substance, without distinction of "cortical" and "medullary" portions. Nor is there any "pelvis" of the kidneys in which the uriniferous tubules empty together by numerous ducts as in a common basin. Each *ureter* (Figs. 103, *b;* 104, *e;* 105, *y*) or excretory duct is formed by reiterated reunion of the *tubuli uriniferi*, after the manner of a pancreatic duct; each ureter passes down behind the rectum and opens into the lower back part of the cloaca—much like a mammalian ureter into the base of the bladder. The original cavity of the allantois remains to furnish no more of a *urinary bladder* than some special dilatation of the cloaca represents; but this rudimentary bladder, as distinguished from the urogenital sinus in which the ureters terminate alongside the sperm-ducts, is well marked in some birds; being in the ostrich, for example, a considerable enlargement of the cloaca between the termination of

[1] The matter may be further illustrated by the two figures borrowed from Owen (after Müller). In both figures, the large dark masses, *a*, are the permanent kidneys, whose ducts, *b* in Fig. 103, *e* in Fig. 104, are the ureters, emptying into the cloaca. In Fig. 103, male, *c* is the Wolffian body, whose duct, *d*, persists as the sperm-duct, conveying semen from *e*, the testis. In Fig. 104, *b* is the Wolffian body, whose duct, *f*, disappears; and *g* is the Müllerian duct, becoming the oviduct, to convey the egg from *c*, the ovary. Thus *e*, Fig. 103, and *c*, Fig. 104, are the homologous genital glands, becoming either testis or ovary; but the sperm-duct, *d*, Fig. 103, is not the oviduct, *g*, Fig. 104.

the rectum proper and the urogenital compartment of the sewer. The renal excretion is not watery as in mammals, but semi-solid, and voided with the fæces, of which it forms part.

The kidneys are capped by a pair of small yellowish bodies, the *suprarenal capsules* or **adrenals** (Figs. 103, *f*; 104, 105, *d*), the nature of which is undetermined. They are chiefly interesting to the practical ornithologist from their liability to be mistaken for testes in examining specimens for sex (see p. 68).

Male Organs of Generation.—The *testis* (Lat. *testis*, pl. *testes*, a witness; Fig. 105, *a*) or *testicle* has been already sufficiently noticed as to its general appearance and position (p. 69). As said above, it is the essential male organ, consisting of the primitive indifferent genital gland (Fig. 103, *e*) in its highest state of development as a tubular secretory organ, connected with the remains of the Wolffian body as a part of its efferent structure (*epididymis*; Fig. 105, *b*) and with the original Wolffian duct as its *vas deferens* (Figs. 103, *d*, 105, *c*), or efferent duct, by which the semen is conveyed to the cloaca. The original glands normally remain paired, and both are usually functionally developed to corresponding size, shape, and activity; they remain in their embryonic situation in front of the upper part of the kidneys; and such difference of appearance as they present under different circumstances is mainly seasonal. For birds, as a rule, procreate only at particular times of the year, rarely having more than one or two broods of young: the functional activity and quiescence of the testes correspond, as the enormous swelling of the gland during the breeding season is one of the peculiarities of the bird's organ. This may be related to the absence, in birds, of specially formed *vesiculæ seminales*, or seminal reservoirs; though certain contortions and dilatations of the sperm-ducts which are to be observed may imperfectly answer to detain the secretion until circumstances render it available. The passage of the sperm-duct is along the face of the kidneys, generally in company with the ureters; the opening is by a papilla upon the surface of the urogenital sinus. These papillose terminations of the sperm-ducts are erectile to a degree, and answer the purpose of paired penes in those birds which are not provided with better-formed copulatory parts. *In coitu* the cloacal chambers containing the orifices of the genital ducts are opened, and the more or less protruded papillæ come in contact or close juxtaposition. In cases in which a penis or two penes are developed, the urethral passage is a groove, never a tube, though cavernous and even muscular tissue may be developed; and in any case of such an intromittent apparatus, it has cloacal invagination when not operative. These organs, in all their variety, are of the sauropsidan, not mammalian, type; though in some respects the structure approaches that seen in the non-

placental mammals. No prostate or Cowperian glands exist in birds.

The sole office of the testis, or *oöphoron masculinum*, is the secretion of *semen*, associate structures being simply accessory for the conveyance of that vital substance and its transference to the opposite sex.

FIG. 106.—Spermatozoa of domestic cock, greatly magnified; from Owen, after Wagner and Leuckart.

The seminal *fluid* itself is merely the vehicle of transport of the *spermatozoa*, in which their activity may be freely exercised in their intuitive struggles to gain access to their mates in the ovary. It is literally a "sea of life" in which the minute creatures swim in shoals to their destiny—and their fate in any case is death. If they successfully buffet the waves of fate they find a watery grave in the ovum at last; if that haven be not reached they simply perish in mid-ocean. The spermatozoa, or seminal animalcules, or male *Dynamamœbœ* (Figs. 106, 107), are the exact counterparts of ovarian ova, in so far as they are single-celled animals of a very low grade of organisation; but their activity and intelligence are marvellous, and still more so is the mysterious attribute with which they are endowed of assimilating their protoplasmic substance with that of the ovum; with the result that the thus fecundated ovum is capable of procreating itself by fission for a period until a mass of similar creatures is engendered; from which mass is then speedily evolved the complex body of the Bird.

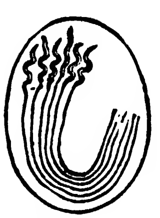


FIG. 107.—Sper- of sparrow, magnified; from Owen, after Wagner and Leuckart.

The corresponding female *Dynamamœbœ* (ovarian ova) are simple spherical animalcules, physically indistinguishable from an ordinary encysted *Amœba;* but the spermatozoa are remarkably distinguished in appearance, furnishing probably the best marked case of sexual characters to be found among the *Protozoa*, to which class of animals they belong. The spermatozoa resemble flagellate infusoria or ciliated endothelium cells, though they each have but a single whip. They are of extremely minute size, much smaller than their females, and filamentous; more or less thickened and sometimes wavy at their nucleated heads, whence protrudes an excessively delicate thready tail, endowed with great vibratory energy. They may be likened to diminutive attenuated tadpoles, which swim by lashing the tail in the seminal fluid. Under the microscope shoals of these curious creatures may be seen swimming in the sea, nosing about in search of the ovum, butting their heads in wrong places, backing out and trying again in another direction; with such success

that out of myriads a score or so may gain their end. It will be seen that they have a long journey to accomplish; for, liberated in the cloaca of the female, they have to swim through the whole length of the oviduct to the ovary. Besides such physical difference between the male and female *Dynamamœbæ* as I have indicated, they differ in their place and mode of birth; and in this difference lies the very gist of sex. The original indifferent genital gland above described, arrested, as said, at a certain stage of development and therefore female—the ovary—produces its eggs from its surface-cells, which subside into the ovarian tissue, and are quietly packed away there as ovarian ova, ready to ripen and awaken to impregnation in due course. The same gland, further developed into a testis, gives active birth to the spermatozoa in the tubules of its complicated interior tissue. In the former case, the superficial cells slowly ovulate; in the latter, the cells lining the interior speedily spermate; in a word, the testis is as literally *viviparous* as is the ovary *oviparous*—and these conditions are certainly no insignificant indices of relative development in the scale of being. The spermatozoa appear in some animals to be set free in myriads from the walls of the seminal tubules whence they directly issue; in birds, they are described as appearing coiled or otherwise packed in delicate sperm-cells, which speedily rupture and discharge the creatures in the current of the seminal fluid, where they take up the course and display the energetic actions above noted. Either case has its parallel among ordinary Protozoans; the former corresponding to the process of budding or gemmation, the latter to that of interior fission and discharge of numerous progeny by rupture of the envelope. The final conjugation of spermatic filaments with ovarian ova is simple fusion, such as any ordinary sexless amœboid animal may practise to blend its protoplasmic substance with that of another. But there is this difference, that in the case of *Dynamamœba* it is a true sexual congress, usually *polyandrous*, and still more of a one-sided affair in that the female *Dynamamœba* is at the time in a more or less quiescent *encysted* state.

Female Organs of Generation.—The connection between the male and female organs of generation is naturally so close that in what has preceded it has been scarcely possible to speak of the former without reference to the female counterparts. I have thus far endeavoured to state clearly the nature of the originally sexless genital gland; the difference in the same gland when afterward sexed male or female; and the character of the spermatic offspring of the male gland. In reading that lesson the novice in such Eleusinian mysteries must not mistake the language I have used to describe the male *Dynamamœba*, or spermatozoön, as applicable to anything in the development of the female *Dynamamœba*, or ovum, into

the chick; for all said thus far only relates to the bringing of the spermatozoön into contact with the ovum, preliminary to the initial step of the ovum in its course of development. It is this female *Dynamamœba*—this primitive ovarian ovum, the germ of the chick, which corresponds to and is the counterpart of the male *Dynamamœba*, on meeting and mingling with which fecundation is accomplished; the impregnated ovum being then empowered to take up its marvellous march. Conjugation of the opposite *Dynamamœbæ* occurs either in the ovary or upper part of the oviduct—most probably the former. One or several spermatozoa—usually more than one—accomplishing their journey up the oviduct, and finding their affinity, insinuate themselves into the substance of the ovum, and die there, dissolved in amorous pain; that is to say, they melt into the substance of the ovum. The now fertile result, consisting of the mingled protoplasm of the opposite amœbas, is to all appearance precisely the same as the original infecund ovum—yet there is all the difference in the world, as the result shows.

FIG. 108.—Female organs of domestic fowl, in activity; from Owen, after Carus. *a*, *b*, *c*, *d*, mass of ovarian ova, in all stages of development; *b*, a ripe one; *c*, its stigma, where the ovisac or calyx ruptures; *d*, a ruptured empty calyx, to be absorbed; *e*, infundibulum, or funnel-shaped orifice of the oviduct; *f*, next portion of oviduct; *g*, follicular part of oviduct; *m*, mesometry, membrane steadying the oviduct the reference-line, *m*, crosses the constricted part or isthmus of the oviduct; these parts secrete the white of the egg; *k*, shell-forming or uterine part of oviduct, in which is a completed egg, *i*; *l*, lowest or vaginal part of oviduct, opening into urogenital sinus of the cloaca, *n*; *o*, anus.

The general character of the ovary of a bird has been already indicated (p. 69). The principal superficial difference in appearance when the ovary is in functional activity from the corresponding organ of a mammal, is that the ova develop to such a size, in ripening in the ovary before leaving it for the oviduct, that the organ looks like a bunch of grapes—very large and conspicuous. The oviduct is the musculomembranous tube (modified Müllerian duct) which conveys the ripened ovum, and in its passage provides it with a quantity of white albumen, and finally a chalk shell. A bird's oviduct is the strict morphological homologue (p. 103) of a mammal's Fallopian tube, uterus and vagina—more accurately, of one Fallopian tube, one-half of a uterus, and one-half of a vagina; for the uterus and vagina of a mammal result from the union of

both Müllerian ducts; whereas in a bird only one—the left usually—is normally developed. Functionally, the oviduct is also analogous (p. 103) to the mammalian uterus, inasmuch as it transmits the product of conception, and detains it for a while, in the initial stage of its germination, as we shall see in the sequel; though all but the very first steps in the development of the chick are taken during incubation, the egg having so hastily left its uterine matrix. These structures—ovary and oviduct, Fig. 108—are most conveniently described as we trace the course of the ovum from its origination to its maturity. This record differs considerably from the corresponding course of events in a mammal, inasmuch as the ovum of a bird, though primitively identical with that of any other animal, acquires special albuminous and cretaceous envelopes which the mammalian ovum, developed in the body of the parent, does not require. The process is termed *ovulation*. Ovulation, which is the formation of an egg in the bird, must not be confounded with *germination*, which is the formation of a bird in the egg. The former can be accomplished by the virgin bird, which may lay eggs scarcely differing in appearance from those which have been fecundated, but germination in which is of course impossible. The course of ovulation, and afterward of germination, is now to be traced.

Ovulation.—The *ovum* begins as a microscopic point in the ovary, the *stroma* or tissue of which is packed with these incipient eggs. It is primitively just like any other female *Dynamamœba*, from that of a sponge up to that of a woman—a naked simple cell, capable of exhibiting active amœboid movements. It consists of a finely granular protoplasm, the *vitellus*, or *yelk*, enclosed in a delicate structureless cell-wall, the *vitelline membrane*, called the *zona pellucida* from its appearance under the microscope. Imbedded in the vitellus is a nucleus, or kernel, the *germinal vesicle;* in this is a nucleolus, or inner kernel, the *germinal spot*. The ovum occupies a tiny space in the ovary, the cellular walls of which constitute an *ovisac*, or *Graafian follicle*. Now if such an ovum as this were mammalian, it would, without material change, burst the ovisac, be received into the Fallopian tube and conveyed to the uterus; where, supposing it already fertilised, the whole of its contents would develop into the body of the embryo. It would therefore be *holoblastic* (Gr. ὅλος, *holos*, the whole; βλαστικός, *blastikos*, germinative). It is different with a bird or other "oviparous" animal, the egg of which has to hatch outside the body; for provision must be made for the nourishment of the developing chick, thus separated from the tissues of its mother. Such provision is made by the accumulation about the ovum of a great quantity of granular protoplasmic substance, which forms nearly all the large yellow ball called in ordinary language "the yelk" of an egg. None of this adventitious substance goes to

form the embryo; it is what the embryo feeds on during its formation. A bird's egg is therefore *meroblastic* (Gr. *μέρος*, *meros*, a part, and *βλαστικός*), and we must carefully discriminate between the great mass of yellow *food-yelk*, as it may be called, and a small quantity of "white yelk," the true *germ-yelk*, which alone is transformed into the body of the chick. The latter forms the *cicatricle*, vulgarly called the "tread"; that small disc, visible in most birds' eggs to the naked eye, which appears upon the surface of the great yellow ball, floating in a pale thin yelk which penetrates the denser and yellower food-yelk by a cord of its own substance leading to a central cavity, the false-yelk cavity, around which the food-yelk is deposited in a series of concentric layers like a set of onion-skins. The whole mass is surrounded by a delicate structureless yelk-skin, called the *vitelline membrane* (whether this be the original vitelline membrane of the *Dynamamœba* or not; *i.e.* whether the food-yelk has accumulated inside or outside the original *zona pellucida*). All this enormous accumulation, effecting what is called a *metovum* or after-egg to distinguish it from the *protovum*, or primitive state of the egg, goes on in the ovary, and in the ovisac of each ovum; with the ripening of the ovum, the ovisacs become distended to a corresponding size, and the whole ovary acquires the familiar bunch-of-grapes appearance. With such maturation of the fruit, the connection with the rest of the ovary lengthens into a stalk, or *pedicel*, by which the ripe ovum hangs to its stock, like any fruit upon its stem, ready to burst its skin and fall into the open mouth of the oviduct. Such rupture of the Graafian follicle (ovisac), in its now distended state known as the *capsule* or *calyx*, occurs along a line where the numerous blood-vessels which ramify upon its surface appear to be wanting, called the *stigma:* this is rent; the ovum slips out of its calyx, like the substance of a grape pinched out of its skin, and falls into the oviduct. After this discharge, the empty calyx collapses, shrivels, and ultimately disappears by absorption. (See explanation of Fig. 108.)

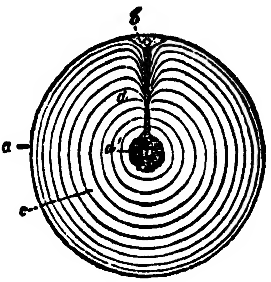


FIG. 109.—Meroblastic ovum (yelk) of domestic fowl, nat. size, in section; after Haeckel. *a*, the thin yelk-skin, enclosing the yellow food-yelk, which is deposited in concentric layers, c, *d*; *b*, the cicatricle or tread with its nucleus, whence passes a cord of white yelk (here represented in black) to the central cavity, *d'*.

The ovum thus acquires the full size of its yelk in the ovary—becoming, as in the case of the hen, a yellow sphere an inch in diameter.[1] Notwithstanding its enormous distension with food-

[1] How great this is can only be appreciated by comparison. The human egg, on

yelk, it is still morphologically a simple cell, affording the maximum dimension of any known protozoan or single-celled animal. Entering the oviduct, the germ-yelk part of the whole mass is fertilised by spermatozoa, unless this process has before occurred in the ovary, and in its passage through that tube the yelk-ball becomes invested successively with the mass of transparent albumen known as the "white" of the egg, and finally by the chalk shell—both secreted by the mucous membrane lining the oviduct.

During its functional activity, the left oviduct (there being usually only this one) becomes highly developed, both as to its muscular walls, which by their contractility embrace the ovum closely and squeeze it along, and as to its mucous secretory surface. It is supported by peritoneal folds forming a *mesometry*, like the mesentery of the intestines; its whole structure and office are quite like those of a length of intestine. The upper end of the singularly serpentine oviduct is dilated into an *infundibulum*, or funnel-like mouth, corresponding to the fimbriated extremity of the mammalian Fallopian tube, and constituting a *morsus diaboli*, or "devil's grip," which gets hold of the ovum to drag it down to the common lot of mortals from its high ovarian birth. The infundibulum receives from the mesentery a delicate tunic of unstriped muscular fibres, which are so disposed as to dilate that orifice for the reception of the ovum; and during the venereal orgasm the mouth of the tube is supposed to seize upon the ripest egg. The actual anatomy of the arrangement, and the whole operation, is strangely suggestive of one of the oldest myths respecting the serpent which bore the egg of the world in its jaws. The mucous lining of the oviduct consists of a layer of ciliated epithelium; the membrane has a different character in successive portions of its extent. Above, when the tube is not distended with its burthen, the lining is thrown into lengthwise folds, which lower down become spirally disposed, and then longitudinal again before they cease. This rugous portion of the tube is beset with mucous follicles, which secrete "the white." The oviduct, after contracting at a point called the *isthmus*, enlarges to a calibre sufficient to accommodate the egg in its shell; for this is the shell-forming part, homologous with the mammalian uterus (a sinister semi-uterus at least), lined with large villi, and beset with the follicles whose secretions calcify

escaping from the Graafian follicle, is said to be from $\frac{1}{240}$ to $\frac{1}{120}$ of an inch in diameter. Taking it at $\frac{1}{200}$, there would be 40,000 in a square inch, and in a cubic inch 8,000,000. The largest bird's egg known, that of the *Æpyornis*, is said to have a content of about a gross of hen's eggs—144. Supposing the yelk of the *Æpyornis* egg to bear the usual proportion to the other contents of the shell, and allowing for the difference in bulk between a sphere and a cube of equal diameters, there would still be somewhere about a billion human eggs in one *Æpyornis* egg-yelk—roundly, a mass of them equal to that of the germs of more than one-half of the present population of the globe.

The deposition of the white and of the shell remains to be noticed. The first deposit upon the yelk-ball consists of a layer of dense and somewhat tenacious albumen, called the *chalaziferous membrane* (Gr. χάλαζα, *chalaza*, a tubercle, and Lat. *fero*, I bear). As the egg is urged along by the peristaltic action of the tube, it acquires a rotation about the axis of the tube; the successive layers of soft albumen it receives are deposited somewhat spirally; and the chalaziferous membrane is drawn out into threads at opposite poles of the egg. These threads, which become twisted in opposite directions during the rotation of the egg, are called *chalazæ;* they are the "strings," rather unpleasantly evident in a soft-boiled egg, which serve the important office of mooring and steadying the yelk in the sea of white by adhesions eventually contracted with the membrane which immediately lines the shell. They are also entrusted with the duty of ballasting, or keeping the yelk right side up. For there is a "right side" to the yelk-ball, being that on which floats the cicatricle, or "tread." This side is also the lightest, the white yelk being less dense than the yellow; and the chalazæ are attached a little below the central axis. The result is, that if a fresh egg be slowly rotated on its long axis, the tread will rise by turning of the yelk-ball in the opposite direction, till, held by the twisting of the chalazæ, it can go no farther; when, the rotation being continued, the tread is carried under and up again on the other side, resuming

FIG. 110.—Hen's egg, nat. size, in section; from Owen, after A. Thompson. *A*, cicatricle or "tread," with its nucleus, of white germ-yelk, floating on surface of pale thin nutritive yelk, leading to central yelk-cavity, *x*; *a*, the yellow yelk-ball, deposited in the successive layers, forming a set of *halones*, and enveloped in the chalaziferous membrane which is spun out at opposite poles into the twisted strings, chalazæ, *c*, *c*; *b*, *b'*, successive investments of softer white albumen; *d*, membrana putaminis, the "soft shell" or egg-pod, between layers of which at the great end of the egg is the air space, *f*; *e*, the shell.

its superior position as before. After all the spiral layers of soft white are laid on, a final covering of dense albumen is deposited at the isthmic part of the oviduct. This forms a tough tunic called the *membrana putaminis* (Lat. *putamen*, a peel, rind), or "egg-pod"; it is the final envelope of such a "soft-shelled egg" as a hen drops when deprived of the lime required to enable her to secrete a hard shell. In the uterine dilatation of the oviduct a thick white fluid charged with earthy matter is exuded; this condenses upon the egg-pod and forms the shell. The composition of this earth is chiefly carbonate of lime (common chalk), with some carbonate of magnesia, and phosphates of both of these bases—thus like that of bone as to ingredients, but in very different proportions. The shell does not simply overlie the pod in a distinct sheet, but is intimately coherent, the microscopic crystals or other particles of the earthy matter being deposited in the matted fibrous texture of the pod. The connection is most intimate in fresh eggs; after a while, layers of the pod separate at the butt of the egg, forming the large air-space which every one has noticed in that situation. The shell being very porous, readily admits air. The air-space enlarges during incubation, and the pod becomes more and more distinct from the shell, which latter also increases in porosity and fragility toward "full term." The rough or smooth appearance of an egg-shell, the pores which may be visible to the naked eye, and other physical characters, are due to the impression made upon it by the lining membrane of the "uterus." The superficial deposit of chalk is so heavy, in some cases, as those of cormorants, etc., that it may be scraped off without interfering with the texturally firm shell-substance underlying. All the coloration of egg-shells, which frequently makes them pretty objects, is simply the deposit of pigment granules in or upon the shell. Such deposit may be perfectly uniform, as it is in the bluish-green egg of a robin (*Turdus migratorius*), for instance, but it is oftener spotty—either upon a white or a whole-coloured ground. The browns and neutral tints are the usual colours, particularly a bright reddish-brown; the same, lying in instead of upon the shell, gives the grays, "lilacs," and "lavenders" so well known. In ptarmigan, the pigment is so heavily deposited that the egg comes out pasty on the surface; a sign of "fresh paint!" one must not disregard if he would not spoil the decoration.

Oviposition.—The energy and rapidity with which the processes involved in the manufacture of so complex a product as a bird's egg is now seen to be are extraordinary. A domestic fowl may lay an egg every day for an indefinite period. It is difficult to say how quickly an egg may ripen in the ovary; for, during the activity of that organ, several or many are to be found in all stages of im-

in twenty-four hours, most of which time is consumed in the shell-formation. The number of eggs matured by the human female is or should be thirteen annually; this is no large number for many of the gallinaceous and anatine birds to deposit in about as many days. But a probable average number is five or six. Defeat of the procreative instinct from any accident is commonly a stimulation to renewed endeavours to reproduce; and very many birds rear two or three broods annually, though one clutch of eggs is the rule. Many, such as auks, petrels, and penguins, lay a single egg. Two eggs is the rule in humming-birds and pigeons. Three is normal to gulls and terns, though these often have but two. Four is the rule among the small waders of the limicoline groups. Some of the small *Oscines* lay over the average, having eight or ten; among these, the European sparrow, *Passer domesticus*, is probably the most prolific. The parasitic cuckoos are said to lay the relatively smallest eggs; that of the *Apteryx* is said to be the largest, weighing one-fourth as much as the bird. The usual *shape* of an egg has given us the common names *oval*, *ovate*, and *ovoidal*, for the well-known figure. Some, as those of owls, woodpeckers, kingfishers, and others, more or less nearly approach a spherical shape. Eggs of grebes, herons, totipalmate birds and various others are rather elliptical, or equal-ended, and narrow in proportion to their length. Eggs of the limicoline group are generally pyriform,—very broad at one end and narrow at the other. But the eggs of all birds vary more in size and shape than some of the devotees of theoretical oölogy admit in their practice. The variation so well known in any breed of domestic fowl is scarcely above a normal rate. The short diameter, corresponding to the calibre of the oviduct, is less variable than the long axis; for when the quantity of food-yelk and white, upon which the difference in bulk depends, varies with the vigour of the individual, the scantiness or redundancy is expressed by the shortening or lengthening of the whole mass. The egg traverses the passage small end foremost, like a round wedge, with obvious reference to ease of parturition by more gradual dilatation of the outlet.

Germination.—Leaving now all the accessory parts of an egg, let us confine attention to the *germ-yelk*, or "tread," which is alone concerned in the germinative process. Recurring to the female *Dynamamœba*, consisting of granular protoplasm (vitellus) included in its cell-wall (vitelline membrane) and including its nucleus and nucleolus (germinal vesicle and germinal spot), we will trace it up to the time it begins to take shape as an embryo chick. At first,

as I have observed before, it is like any other amœba; the first step of development is probably a retrograde one; for if there ensues, when the spermatozoa melt into the ovum, the result affirmed for mammalian ova, the original germinal vesicle and germinal spot *disappear*, and the whole content of the ovum proper is simply a homogeneous mass of granular protoplasm. In this retrograde step, the organism, at the lowest possible round of the ladder of evolution, is called a *monerula*. The germinal vesicle and spot, however, are speedily reconstructed, and the ovum looks precisely as it did before. But observe that the actual difference is enormous; for it

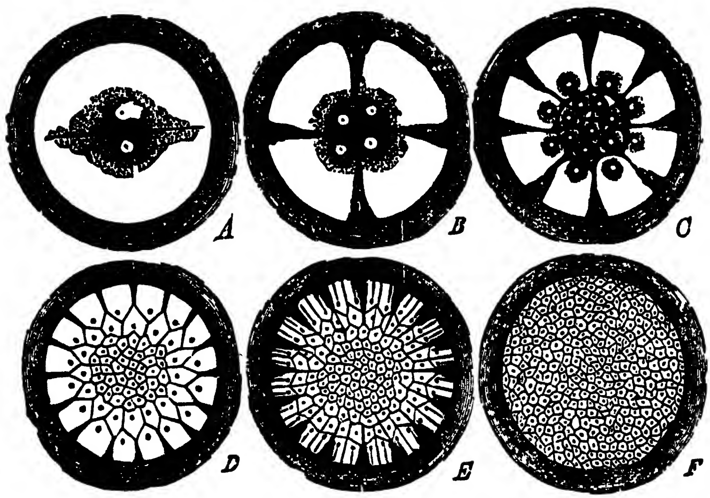


FIG. 111.—Segmentation of the vitellus by discoidal cleavage, diagrammatic, ×about 10 times, after Haeckel. Only the "tread," cicatricle, or germ-yelk (Figs. 109, *b*, 110, *A*) is represented, as no other part of the whole yelk-ball undergoes the process. *A*, separation into 2; *B*, into 4; *C*, into 16, by 8 radial and 1 concentric furrow; *D*, into many parts, by 16 radial and about 4 concentric furrows; *E*, 64 radial and about 6 concentric furrows; *F*, the whole tread broken up into a mulberry-mass (*morula*) of cells.

now consists of the blended substance of the original ovum and of the spermatozoa; and in this duplex or bisexed state, before any further step is taken, the creature is called a *cytula*,—the parent cell of the entire future organism. In the former state it could reproduce nothing, not even itself; for it is the strange physiological law of a *Dynamamœba* that it cannot reproduce like an ordinary cell, but must evolve an entire organism, like both of those two whose vital forces it concentrates, summarises, and embodies,—or nothing.

The first change in the parent-cell is that by which it becomes broken up into a mass of cells, each of which is just like itself. This process is called *segmentation of the vitellus;* each one of the numerous resulting cells is called a *cleavage-cell*. The nucleus of

the parent-cell divides into two; each attracts its half of the yelk; the halves furrow apart and there are now *two* cleavage-cells in place of the one parent-cell. A furrow at right angles to the first, and redivision of the nuclei, results in *four* cleavage-cells. Radiating furrows intermediate to the first two bisect the four cells, and would render *eight* cells, were not these simultaneously doubled by a circular furrow which cleaves each, with the result of sixteen cleavage-cells. So the subdivision goes on until the parent-cell becomes a mass of cells. This particular kind of cleavage, by radiating and concentric furrowing, is called *discoidal*, and the resulting heap of little cells assumes the figure of a thin, flat, circular disc. Segmentation of the vitellus, in whatever manner it may go on, results in a mulberry-like mass of cleavage-cells; and the original cytula has become what is called a *morula*. This process and result are clearly shown in Fig. 111, *A-F*.

The morula or mulberry-massed germ of which the "tread" of a bird's egg at this moment consists increases by multiplication of cells, and the disc is lifted a little away from the mass of yellow food-yelk upon which it rests, like a watch-crystal from the face of a watch. This disposition of the greatly multiplied cells in a *layer* and their coherence forms of course a *membrane*,—the *blastodermic membrane*, or *blastoderm* (Fig. 112, *B*, *b*). The cavity between the blastoderm and the mass of food-yelk is called the *cleavage cavity*, *s*. At the stage when the blastodermic membrane and cleavage-cavity are formed, the germ is called a *blastula*, or *germ-vesicle*,[1] and the process by which the morula becomes a blastula is called *blastulation*. Next, from the thickened rim, *w*, of the watch-crystal-like blastula a layer of large *endoderm* cells (Fig. 112, *C*, *i*) separates, and grows toward the centre: when it gets there, of course the original cleavage-cavity, *s*, is shut off from the surface of the food-yelk; a second crystal having grown under the first one. The second adheres to the first, obliterating the original cleavage-cavity; the germ is now obviously *two-layered;* the rising of the inner layer to meet the outer results in a cavity between itself and the food-yelk, *D*, *d*. This cavity exactly resembles the original cleavage-cavity, but it is a very different thing, being the primitive *intestinal cavity*. The blastula, or germ-vesicle, has become converted into a *gastrula* by the invaginating process just described, known as *gastrulation*. The gastrula of a bird has the circular discoidal form which causes it to be termed a *discogastrula*. This process of forming a single blastodermic layer, with a cleavage-cavity (blastula, or true germ-vesicle), then two blastodermic layers, with obliteration of the cleavage-cavity and substitution of a primitive intestinal cavity

[1] Not to be confounded with the original "germinal vesicle" of the parent-cell, which long since disappeared.

(gastrula), is common to all animals which consist of more than single cells, under various modifications and disguises; the process described is that occurring in meroblastic eggs which have a discoidal cleavage and form a discogastrula.[1]

What we have got now is a tread or germ consisting of a circular concavo-convex disc of two layers of blastoderm, resting by its rim upon the great yellow ball of food-yelk, from which it is separated by a cavity, as a watch-crystal from its face. All these changes, up to completion of gastrulation, may go on *before the egg is laid*, the tread of a perfectly fresh egg being already a multicellular

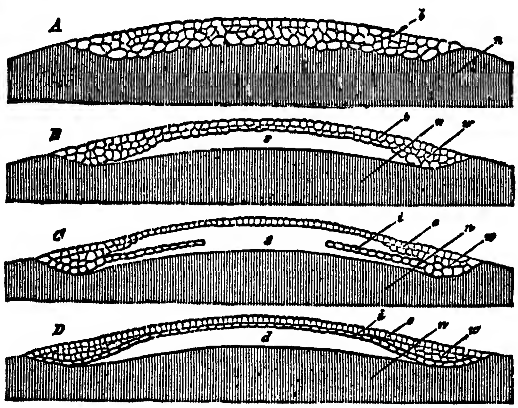


FIG. 112.—Further development of hen's egg; after Haeckel: *A*, the mulberry mass of cleavage cells, *b*, same as seen on top in Fig. 111, *F*, here viewed in profile in section, resting upon *n*, the simply-shaded part of the figure, to represent conventionally the mass of food-yelk. *A*, morula stage (as before); *B*, blastula stage, the mass of cells, *b*, forming the blastoderm, uplifted from the food-yelk, leaving the cleavage-cavity, *s*; *w*, the thickened rim of the germ-disc; *C*, the blastula in process of inversion, by which a layer of endoderm-cells, *i*, growing from periphery to centre, will apply itself to the layer of exoderm-cells, *e*, obliterating the cleavage-cavity, *s*; *D*, the discogastrula completed, by union of endoderm, *i*, with exoderm, *e*, leaving the primitive intestinal cavity, *d*, which is quite similar in appearance to the cleavage cavity, *s*, but morphologically quite different.

discogastrula. Since the earlier stages of the embryo (cytula, morula, blastula, and gastrula) are actually accomplished while the egg is still in the body of the parent, the analogy of the oviduct to uterus, etc., as well as its strict homology to the parts of a Müllerian duct so named, is not so fanciful as some appear to think. The outer of the two blastodermic layers is the *ectoderm* or *epiblast*, *C* or *D*, *e*; the inner is the *endoderm* or *hypoblast*, *i*. By multiplication of cells between the two arises the *mesoblast*. The mesoblastic layer of cells subsequently splits into two, of which the outer is the *somatopleura*, or body layer, the inner the *splanchnopleura* or visceral layer. The two-layered germ has then become four-layered. Up to the

[1] The so-called "germ-vesicle" of the holoblastic mammalian egg is subsequent to gastrulation, not prior, and is therefore not a blastula proper.

time of formation of four layers, the cells are all alike, or only differ slightly in size, colour, or consistency. Now, however, ensues that marvellous process by which the indifferent cells of the blastodermic layers are to become *differentiated in form and specialised in function*,—a sort of division-of-labour system in the infant colony of cells, by which some are to learn to move, others to digest, others to procreate, others to think and feel, with corresponding modifications of form by which are generated the *Osteamœbæ*, *Myamœbæ*, *Neuramœbæ*,—the bone-cells, muscle-cells, nerve-cells, and all others of the complex organism which is in a few days to come into being from such simple beginnings. This of course opens up the whole field of embryology, which we cannot here enter upon. I will only add, that from the epiblast are derived the integument, and its in-versions, as those of the eye and ear, and the brain and spinal cord. From the hypoblast is derived the lining of the alimentary canal and of its annexes and offsets, as liver, lungs, etc. The rest of the embryo comes from the mesoblast, and most of it from the somatopleural layer. The fissure between the two layers of the mesoblast becomes the great pleuroperitoneal cavity.

In explaining the early embryo, I have closely followed the great German morphologist Haeckel; and the illustrations are from the same high source.

Incubation.—To induce the wonderful metamorphoses just hinted at, it is only necessary to keep a bird's egg at a pretty even temperature of about 100° Fahr. Nearly all birds secure this result by the process of *incubation*. In many cases the sun's rays relieve the parent of some part of the duty. In a few, the heat evolved from vegetable ferment or decomposition is utilised for the same purpose. This seems to be the case to some extent with grebes; but these incubate. "The exception to the rule of incubation is given by the Megapodial birds of the Australasian Islands. A huge mound of decaying vegetable matter is raised; the eggs are deposited vertically in a circle at a certain depth, near the summit, and the chick is developed with the aid of the heat of fermentation. The large size of the egg relates to affording a supply of material sufficing for an unusually advanced state of development of the chick at exclusion; whereby it has strength to force its way to the surface of the hatching-mound, with wings and feathers sufficiently developed to enable it to take a short flight to the nearest branch of an overshadowing tree" (Owen). The period of incubation has been ascertained with precision for few birds; it is known to range from ten days (perhaps less), as in case of the wren, to fifty or sixty for the ostrich. The female is usually the sitter. Frequently both sexes incubate in turn; such unnatural care for the young by the male is termed *double monogamy*. In most or all *Ratitæ*, in the

family *Phalaropodidæ*, and some other Limicoline genera, the male incubates. Most birds attend to their own eggs; many cuckoos (*Cuculidæ*) and the species of *Molothrus*, are parasitical, laying in the nests of other birds, which are thus forced to become foster-parents of alien offspring, generally to the destruction of their own. This seems to result from some peculiarity of the egg-laying process, which does not permit several eggs to be incubated and hatched simultaneously. It is not so unusual among American cuckoos as generally supposed. The degree of development to which birds attain in the egg differs in *Altrices* and *Præcoces* (see p. 131). They break the shell by pecking at it, and struggling; for the former operation the bill is often tempered at the tip by a hard knob which is afterward absorbed. The necessity of providing a receptacle for eggs, in which they may be incubated, results in *nidification* or nest-building; and the extraordinary taste and ability many birds display in this matter, as well as the wide range of their habitudes, furnishes one of the most delightful departments of ornithology, called *caliology* (Gr. καλιά, *kalia*, a bird's nest; see p. 81, note). Many birds burrow in the ground; others in trees; the most beautiful and elaborate nests are furnished by various members of the *Oscines*, the weaver-birds of Africa (*Ploceidæ*) probably taking the lead. The male sometimes constructs his own "nest" apart from that in which the female incubates. "Certain conirostral *Cantores* still practise in the undisturbed wilds of Australia the formation of marriage-bowers distinct from the later-formed nesting-place. The satin bower-bird (*Ptilonorhynchus holosericeus*), and the pink-necked bower-bird (*Chlamydodera maculata*), are remarkable for their construction on the ground of avenues, overarched by long twigs or grass-stems, the entry and exit of which are adorned by pearly shells, bright-coloured feathers, bleached bones, and other decorative materials, which are brought in profusion by the male, and variously arranged to attract, as it would seem, the female by the show of a handsome establishment" (Owen). The extraordinary nests of the *Crotophaga* are used in common by a colony of the birds. "Edible birds' nests," constructed by swifts of the genus *Collocalia*, consist chiefly of seaweeds and inspissated saliva. Perhaps the most remarkable of all the receptacles of eggs is that which the penguin makes of its own body, the egg being taken in a sort of pouch formed by the integument of the belly, something like that of a marsupial mammal.

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THE END

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